



# **OPTIMIZATION OF BAGASSE ASH TO CEMENT MIX**

## **PROPORTION FOR M30 GRADE CONCRETE**

**BY**

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I hereby declare that this thesis entitled “**Optimization of Bagasse Ash to Cement Mix Proportion For M30 Grade Concrete**” was composed by myself, with the guidance of my advisor, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted, in whole or in part, for any other degree or professional qualification.

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## CERTIFICATE

This is to certify that the thesis prepared by **Teshale Feyera Goshu** entitled “**Optimization of Bagasse Ash to Cement Mix Proportion for M30 Grade Concrete**” and submitted in fulfillment of the requirements for the Degree of Master of Science complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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## ABSTRACT

*This study was focus on the optimization of bagasse ash to cement mix proportion and suitability of bagasse ash as a cement replacing material to minimize the degradation of environment due to cement demand. The grinding of the bagasse ash was done in a small mill at a time and then the bagasse ash size was reduced to fineness similar to that of Portland cement. After reduced the ash size, the complete silicate analysis were investigated for major chemical composition of bagasse ash. The trial mix was prepared for characteristics strength of 30MPa with water to cement ratio of 0.45 and a cement content of 397.8kg/m<sup>3</sup>. For the purpose of preparing a final mix the water to cement ratio of the mix was increased from 0.40 and 0.45 to 0.5 by keeping the cement content constant i.e. water increased from 179kg/m<sup>3</sup> to 198.9kg/m<sup>3</sup>, in order to adjust the slump. The blended pastes like consistency, setting time and soundness investigated at different replacement contents in the ratio of 5%, 10% and 15% by weight of cement. A total of 27 bagasse ash to cement mix concrete with three replicates (81 specimens) should be casted by varying the levels of key factors affecting concrete properties. Fresh concrete that is slump cone test were undertaken as well as hardened concrete test is compressive strength at the age of 28 days was obtained. The optimum values of water/cementitious materials ratio and fine/total aggregate ratios have resulted in a higher compressive strength at lower cementitious materials content resulting in significant cost saving in the concrete production and the compressive strength decreases as the bagasse ash to cement blended increases over 10%. Slightly, all of the bagasse ash to ordinary port land cement mix proportion blended concrete satisfies the ASTM C 618.*

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## LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ACI	American concrete institution
ASTM	American Society for Testing Materials
BA	Bagasse Ash
FA/CA	Fine/Totale Aggregate Ratio
F	Fly Ash
ES	Ethiopian Standard
L.O.I	Loss On Ignition
M30	M is mix...No.30 is the standard strength of the concrete cube after 28 days in N/mm <sup>2</sup> (Mpa)
N	Natural pozzolana
OPC	Ordinary Portland Cement
OD	Oven Dry
S	Silica fume
SCBA	Sugar Cane Bagasse Ash
SSD	Saturated Surface Dry
W/B	Water to Binder ratio
W/C	Water to Cement ratio

# 1. INTRODUCTION

## 1.1. Background

Now-a-days the most suitable and widely used construction material is concrete. This building material, until these days, went through lots of developments. The definition of concrete is a mixture of port-land cement, water; sand and gravel or crushed aggregate which when placed in forms and allowed to cure becomes hard [Qureshi, M., Tandel, Y., & Patel B., 2013], the hardening is caused by chemical action between water and cement by which it gains strength progressively.

The most important part of concrete is cement. The production process of this raw material produces a lot of CO<sub>2</sub>. It is well known, that CO<sub>2</sub> emission initiates harmful environmental changes. Nowadays researchers make efforts to minimize industrial emission of CO<sub>2</sub>. The most effective way to decrease the CO<sub>2</sub> emission of cement industry is to substitute a proportion of cement with other materials.

In order to address all effects associated with cement manufacturing, there is a need to develop an alternative way of supplementary cementitious material by utilizing either industrial or agricultural waste, as a source of raw materials for production of cement, since agricultural and industrial by-products are commonly used in concrete production as supplementary cementitious material, to enhance both fresh and hardened properties of concrete as well as to save the environment from the negative effects caused by their disposal [Meeravali .k, *et al.*, 2014]. The use of pozzolans in concrete production brings positive effects to the environment, since by substituting large quantities of cement in concrete production.

Residual from sugar industry and bagasse bio mass burned under controlled conditions gives ash having amorphous silica, which has been tested in some parts of the world for its pozzolanic property and has been found to improve some of the properties of the concrete like compressive strength and water tightness in certain replacement percentages and fineness [Biruk Hailu, 2011]. The pozzolanic property of bagasse ash came from the silicate content of the ash. This silicate of a pozzolanic reaction with the hydration products of the cement and results a reduction of the free lime in the concrete [Noor Ul Amin, 2010]. The silicate content in the ash was vary from ash to ash depending on the burning and other properties of the raw materials like the soil on which the sugarcane is grown.

Optimizations a process of finding the best result under given circumstances as the process of the conditions that give the maximum or minimum value of a function, such decisions is either to minimize the effect required or to maximize the desired benefit[Shamsad .A and Saeid A. Alghamdi,2014]. Since search for a mixture which the sum of the costs of the ingredients is lowest and recycling of solid waste into a sustainable construction material with optimum mix proportion is the global need to reduce its adverse environmental impacts, and waste utilization is improve quality, reduce the cost of construction materials and environmental pollution control.

Therefore, the cement shall be supplemented by solid waste bagasse ash in the range of (5%, 10%, & 15%) by weight for M30 grade mix concrete. An experimental investigation would be carried out to examine the impact of adding bagasse ash to the mechanical and physical properties of pastes and concretes such as consistency, setting time, soundness, workability, compressive strength and durability.

## **1.2 Statement of the Problem**

The sugar manufacturing industries produce a sugarcane bagasse which is generate energy by using bagasse as fuel for sugar factory also creates a great deal of waste material known as bagasse ash which results in waste disposal problem and environmental pollution disposed of in an open land (landfill).[Aigbodion, V.S. *et al.*,(2010)]

Cement is a common binder and important material that used in construction [Akeem. A and Mutiu. A, 2017]. However, Cement production is one of the most environmental unfriendly processes activities due to CO<sub>2</sub> emissions and Ordinary Portland cement is the conventional building material that actually is responsible for about 5% - 8% of global CO<sub>2</sub> emissions [Bangar Sayali, *et al*, 2017].

The chemical effect relates to the ability of the SCBA to provide reactive siliceous and/or aluminous compounds to participate in the pozzolanic reaction with calcium hydroxide (an unfavourable product from cement hydration) and water [Cordeiro *et al.*, 2008], The product of such reaction is called calcium silicate hydrate, a compound known to be responsible for compressive strength in cement-based material .

Then, this thesis deals with optimized of bagasse ash to cement mix proportion and to study the suitability of bagasse ash produced as a waste in Ethiopian sugar factories for using it as supplementary cementitious material replaced of cement to minimize the degradation of environment due to cement demand.

## **1.3. Objective of the research**

### **1.3.1. General Objective**

The general objective of this research was to investigate the optimization of bagasse ash to cement mix proportion and suitability of bagasse ash as a cement replacing material to minimize the degradation of environment due to cement demand.

### **1.3.2. Specific Objectives**

The specific objectives of this research are:

- To characterize physical and chemical composition of bagasse ash.
- To determine the effect of bagasse ash to cement mix proportion on properties of fresh concrete.
- To determine the effect of bagasse ash to cement mix proportion on properties of hardens concrete.
- To find the optimum % of bagasse ash to cement mix proportion for M30 grade concrete.

#### **1.4. Significance of the Research**

The significance of this research would be contributed in maximizing bagasse ash to cement mix proportion for M30 grade concrete and minimizing the effect of waste material on the degradation of environment due to cement demand. This waste utilization was improving quality of concrete and reduces the cost of construction materials. It serves as an environmental pollution control for producing concretes that used on structure with new properties.

#### **1.5. Scope of the Research**

The main scope of this study was conducted experimental investigation on optimization bagasse ash to cement mix proportion for M30 grade concrete, as the process of finding the conditions that give the maximum or minimum value of a function, and experimental result analysis focus on the characterization of physical and chemical composition of bagasse ash, fresh property and hardened property of concrete, such as consistency, setting time, soundness, workability, compressive strength and durability.

## **2. LITERATURE REVIEW**

Environmental pollution due to development in modern industrial practice is one of the most significant problems of this century. The cement and concrete technology has shown various advancements during the past years [Biruk Hailu, 2011]. Demand and consumption of cement is increasing day by day which has led researchers and scientists to search for locally available alternate binders that can replace cement partially and are eco-friendly and contribute towards waste management [Bangar Sayali, *et al*, 2017]. Bagasse ash is one of the by-product materials found from sugar factories. Recently it has been studied for its feasibility as a cement replacing material in some parts of the world and has been found to improve some of the properties of concrete. The performance of concrete is assessed by different tests on both the fresh and hardened concrete. That discussing about cement, different performance criteria of concrete, pozzolans and bagasse ash.

### **2.1. Binder**

Binder(Cement) is the second most consumed material on the planet next to water[Aigbodion*etal.*,2010) suggested that it is an essential component of infrastructure development and most important input for construction industry, particularly in infrastructure and housing programs, which are necessary for the socioeconomic growth and development. As stated above, cement plays a central role in concrete by providing an inert medium (the cement paste) in the plastic state and by ensuring proper bonding between the different ingredients, and also with the reinforcement, after hardening[Noor Ul Amin,2010]. It is primarily prepared by combining predetermined proportions of calcareous material such as limestone or chalk and silica and alumina commonly found as clay or shale.

#### **2.1.1. Types of Binder (Cement)**

There are different types of Binder (Cement) depending on their composition, method of manufacturing (grinding, burning, etc.) and also the relative proportion of the different compounds.

The following varieties are most common

**Ordinary port land cement (OPC)** – is used for all types of construction, such as foundation walls, and slabs



**Rapid hardening port land cement (RHC)** – maximum strength is obtained in 3 Days. This cement is more fine grained and contains higher proportion of  $3 \text{ CaSiO}_2$ . RHC is used in special Constructions where an early strength is required.

**Low heat cement (LHC)**- has lower line content and higher silica and iron Content than ordinary port land cement .The heat of hydration is generated much more slowly and is about one third less than that of OPC. LHC is used in Massive structures like dams.

**Quick setting cement (QSC)** – doesn't contain gypsum and consequently sets and hardens within 30 minutes. It is used for under water construction.

**Pozzuolana cement (PPC)** – is made by mixing pozzuolamic material with OPC Clinker and grinding then together in the cement mill. It is used in seashore construction, as it is more resistant to sulphates and corrosive action of seawater.

One of these types and the most commonly used one is Portland cement, which in turn is divided into many types of cement classes.

#### **2.1.1.1. Ordinary Portland cement (OPC)**

Modern Portland cement is made from materials which must contain the proper proportions of lime ( $\text{CaO}$ ), silica ( $\text{SiO}_2$ ), alumina ( $\text{Al}_2\text{O}_3$ ), iron ( $\text{Fe}_2\text{O}_3$ ) with minor amounts of magnesia and sulfur trioxide. These four major compounds determine the hydraulic properties of cement because they account for over 90 % in Portland cement [Zhi Ge, 2005]. Portland cement is one of the most widely used cement and is the most important hydraulic cement.

The origin of the name "Portland cement" is usually attributed to Joseph Aspdin, a brick mason in England who in 1824 took out a patent for making a powder made from mixed and ground hard limestone and finely divided clay. This forms into slurry and then is calcite in a furnace till the  $\text{CO}_2$  was expelled. He called the resulting material Portland cement because when the mortar made with it hardened it produced a material resembling the stone which was quarried near Portland, England [Shetty M.S., 2005]. Cement is primarily composed of alite ( $\text{C}_3\text{S}$ ), belite ( $\text{C}_2\text{S}$ ), aluminate ( $\text{C}_3\text{A}$ ), and alumino ferrite (CAF). Despite of their small percentages, the minor compounds can also have strong influence on the properties of fresh and hardened cement paste. The method of making cement has been improved upon since that time but the basic process has remained the same. The typical composition of Ordinary Portland Cement (OPC) is listed in Table 2.1.

Table 2-1. Typical composition of Ordinary Portland cement [Mindess *et al.*, 2003]

Chemical Compound	Oxide composition	Abbreviation
<b>I. Major compounds</b>		
Tricalcium silicate	3CaO.SiO <sub>2</sub>	C <sub>3</sub> S
Dicalcium silicate	2CaO.SiO <sub>2</sub>	C <sub>2</sub> S
Tricalcium Aluminate	3CaO.Al <sub>2</sub> O <sub>3</sub>	C <sub>3</sub> A
Tetracalcium aluminoferrite	4CaO. Al <sub>2</sub> O <sub>3</sub> . Fe <sub>2</sub> O <sub>3</sub>	C <sub>4</sub> AF
<b>II. Minor compounds</b>		
Gypsum	CaSO <sub>4</sub> .2H <sub>2</sub> O	CSH <sub>2</sub>
Free lime	CaO	C
Magnesium oxide	MgO	M
Alkali Oxides(Na <sub>2</sub> O and K <sub>2</sub> O)		

Of the all, silicates C<sub>3</sub>S and C<sub>2</sub>S are the most important compounds, which are responsible for the strength of hydrated cement paste. The presence of C<sub>3</sub>A in cement contributes to early strength. C<sub>4</sub>AF is also present in cement in small quantities and compared with other three compounds; it does not affect the behavior significantly. High percentages of C<sub>3</sub>S (low C<sub>2</sub>S) results in high early strength but also high heat generation as the concrete sets. The reverse combination, that is, low C<sub>3</sub>S and high C<sub>2</sub>S develops strength more slowly and generates less heat. C<sub>3</sub>A causes undesirable heat and rapid reacting properties, which can be prevented by adding CaSO<sub>4</sub> to the final product.

The most common classification of Portland cement is that of ASTM. It classifies Portland cement mainly into five groups (non-air entrained) differing only on the relative amount of the compounds and the degree of fineness.

- ASTM type I this type of cement is used in constructions when there is no exposure to sulphates in the soil or ground water. Cement is a general purpose Portland cement used when there is no special property required by the concrete.
- ASTM type II cement is Moderate Portland cement. It is also a general-purpose cement to be used when moderate sulphate resistance or moderate heat of hydration is desired.

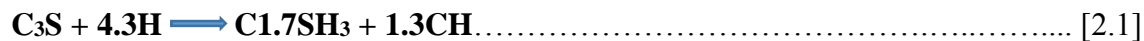
- ASTM type III cement is High early strength Portland cement which is used when high early strength is desired, usually less than one week, it is usually used when a structure must be put into service as quickly as possible.
- ASTM type IV cement is Low -Heat of Hydration Portland cement which is used, when a low heat of hydration is required, like in mass concrete.
- Finally ASTM type V is Sulphate -resisting Portland cement which is used when high sulphate resistance is desired.

### **2.1.2. Chemical and Physical Properties of Binder (Cement)**

The Chemical and physical properties of the cements should be used to evaluate the properties of the cement, rather than the concrete which is the result of cement. An understanding of the significance of some of the Chemical and physical properties is helpful in interpreting results of cement tests.

#### **2.1.2.1. The chemical reaction of Binder**

The chemical reaction of the cement and the water is called hydration and it results in new compounds called hydration products. Both  $C_3S$  and  $C_2S$  react with water to produce an amorphous calcium silicate hydrate known as C–S–H gel which is the main ‘glue’ which binds the sand and coarse aggregate particles together in concrete. When water and Portland cement are mixed, the constituent compounds of the cement and the water undergo a chemical reaction resulting in hardening of the concrete [Birhanu Bogale, 2007]. Each of the compounds found in the cement react with water, but the rate at which they react is different.  $C_3S$  and  $C_3A$  are the most reactive compounds, whereas  $C_2S$  reacts much more slowly. Approximately half of the  $C_3S$  present in typical cement will be hydrated by 3 days and 80% by 28 days, in contrast, the hydration of  $C_2S$  does not normally proceed to a significant extent until approximately 14 days [John Newman and Ban Seng Choo, 2003]. Gypsum is added to lower the rate of hydration of  $C_3A$ . The hydration of  $C_3S$  and  $C_2S$  are shown in Eq.2.1 and Eq.2.2 [24].



After a rapid initial reaction  $C_3S$  will pass through a dormant stage which has a practical significance because it allows concrete to be placed and compacted before setting and hardening commences.

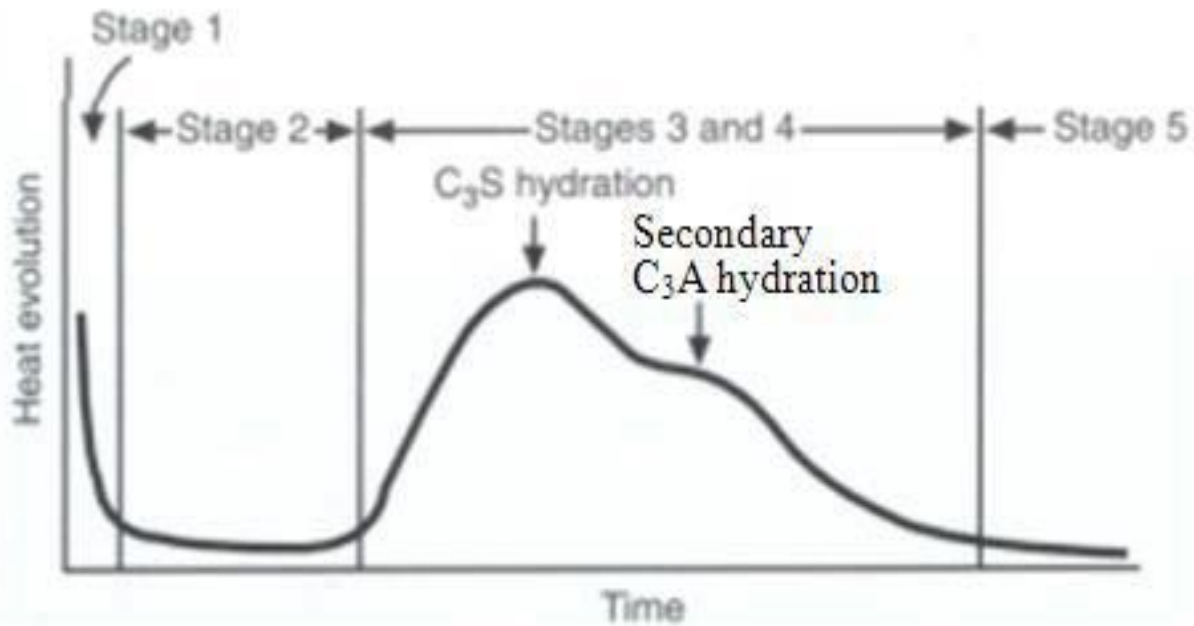


Figure 2.1. Heat of hydration of a cement paste

The rate and amount of heat of hydration are affected by various factors. Among these cement composition and fineness, water to cement ratio of the concrete, age of the paste and ambient conditions are the most common ones. The hydration of Portland cement as a whole is more complex than the individual compounds. This is because the different compounds have different products, reaction rate, and each of the compounds consumes water. The purpose of adding calcium sulfate is in order to retard the hydration of  $C_3A$ , which without calcium sulfate results in flash set due its high rate of reaction with water. When cement is first mixed with water some of the added calcium sulfate, dissolve rapidly. This is because  $C_3A$  is more reactive than any of the compounds in the cement and if allowed will take much of the water. The order of reaction is  $C_3A > C_3S > C_4AF > C_2S$  [Sidney Mindess, *et al.*, 2003]. But the rate of hydration of these compounds differs from cement to cement depending on the fineness, the rate of cooling of the clinker and other factors like presence of impurities and other cement compounds.

The physical properties of the Portland cements are commonly characterized by their physical properties for quality control purposes. Some of its physical parameters are listed below:-

#### **2.1.2.2. Fineness of Binder (Cement)**

The fineness of cement affects many of its properties [Peter Hewlett, Lea's, 2004]. The heat released and the rates of hydration are the main properties which are affected by the fineness of cement. These properties of the cement in turn affect many other properties, like normal consistency, setting time, strength, etc. Fineness of cement can be measured mainly by specific surface area method and particle size distribution. The specific surface area is the summation of the surface area of all of the particles in 1 gm or 1 kg of cement. Most of the time, it is a general practice to describe fineness by a single parameter, specific surface area [Sidney Mindess *et al.*, 2003]. The surface area is measured by the Blaine air-permeability test (ASTM C 204 or AASHTO T 153) that indirectly measures the surface area of the cement particle per unit mass. According to the Ethiopian standard ordinary Portland cement shall have a specific surface area of not less than 2250 cm<sup>2</sup>/g [Abebe Dinku 2002], whereas the ASTM C 150 standard recommends a minimum of 2800 cm<sup>2</sup>/g.

#### **2.1.2.3. Water Content of Binder (Cement) Paste**

The physical requirements of cement paste like setting and soundness depends on the water content of the neat cement paste. This is defined in terms of the normal consistency of the paste which is measured according to ASTM C 187. The amount of water required to achieve a normal consistency as defined by a penetration of  $10 \pm 1$  mm of the Vicat plunger (ASTM C 187) is expressed as a percentage by weight of the dry cement, the usual range being about 26% to 33% [Abebe Dinku, 2002]. This is sensitive to the conditions under which it is being carried out, particularly the temperature and the way the cement is compacted into the mold which only measures the plasticity of cement paste.

#### **2.1.2.4. Setting Time of Binder (Cement)**

Concrete setting time may be slower with some SCBA used at higher percentages. This can be beneficial in hot weather. The slower setting time is offset in winter by reducing the percentage of SCBA in the concrete. Setting is a process in which cementitious mixtures of plastic consistency is converted into a set material which has lost its deformability and crumbles under the effect of sufficiently great external force [Peter Hewlett, 2004]. It is preceded by a stiffening of the paste in which the apparent viscosity of the material increases without losing its plastic character. There are two types of setting time i.e. initial and final setting times.

Initial setting time is that time period between the time water is added to cement and time at which 1mm square needle fails to penetrate the cement paste, placed in the Vicat's mould 5mm to 7mm from the bottom of the mould that indicates the time at which the paste begins to stiffen considerably and can no longer be molded.

Final setting time is the time elapsed between the moments that the water is added to the cement, and to the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure that indicates the time at which the paste has hardened to the point at which it can sustain some load. Like normal consistency these tests are also used for quality control. Ethiopian standard recommends that the initial setting time for cement not to be less than 45 minutes and the final setting time not to exceed 600 minutes (10 hrs)[Abebe Dinku,2002].

#### **2.1.2.5. Soundness of Binder (Cement)**

The Binder (Cement) paste should not undergo large changes in volume after it has set. However, when excessive amounts of free CaO or MgO are present in the cement, these oxides can slowly hydrate and cause expansion of the hardened cement paste.

Soundness is defined as the volume stability of the cement paste and a Soundness Test conducted by using the Le Chatelier apparatus. The mould is then immersed in water again and brought to a boil. After boiling for 30 min the mould is removed from the water, after cooling, the distance between the indicator points is measured again. This increase represents the expansion of the cement paste for Portland cements; expansion is limited to 10mm.

#### **2.1.3. Cement Production and its effect on the environment**

The two basic methods to produce cement are the wet and dry manufacturing processes. The choice of the process is mainly based on the nature of the available raw materials. When the moisture content in raw materials is more than 20% (and up to 45%), the wet method is preferred to the dry method. In the past, the wet process was mostly preferred because the homogenization of wet raw materials was easier than that of dry powders. The wet process also enables an easier control of the chemical composition of the raw mix. However, the wet process is more energy intensive and cement industry is moving towards more energy efficient dry process technologies.

### **2.1.3.1. The Strategic and Cement production industries in Ethiopia**

Binder (Cement) is an essential component of infrastructure development and most important input for construction industry, specifically in infrastructure and housing programs, which are necessary for the socioeconomic growth and development [FDRE Ministry of Industry, 2015]. As a result, the Government of Ethiopia believes that cement is one of the strategic industries that need to be strategically managed in order to sustain the growth of construction and infrastructure development in the country. The Ethiopian cement industry has endured through three major milestones, i.e., the beginning of cement production and modernizations till 1984, construction boom in 2004 followed by acute shortage and aggressive expansion of the sector in 2012 onwards resulting in inflaming excess capacity. Following the 2004 boom in construction sector, severe shortage of cement was observed. During the period 2003-08, the government increased its infrastructure spending three fold mainly on road, waterworks, public buildings and Dams constructions. Consequently, sustained shortage of cement supply resulted in cement price hike. In 2007 the government responded to the price hike by allowing imports. Hence, the period from 2008-2011 signifies a time of acute shortage of cement that resulted abnormal price hike and excessive reliance on imported cement. For instance in 2008/9 alone, Ethiopia imported around 1.2 Mt of cement. Nevertheless, in 2012, as new and large investments have become operational, the cement price dropped sharply. Similarly, the overall cement production capacities have started to grow substantially due to the growing investment in the industry. Currently, the country has more than 16 cement plants (other than 2 new entrants). In terms of size and installed production capacity: four are large and integrated firm with more than 2 Mta installed cement production capacity; four are mid-sized cement plants with combined installed cement production capacity of 2.3 Mta [FDRE Ministry of Industry,2015], while the balance are small cement plant with vertical shift kiln technology including clinker grinding facilities. Import of cement except special cement and new investment has been temporarily halt by the government since March 2012. The existing installed production capacity (December 2014) is 11.2 Mta excluding temporary shutdowns and is expected to grow to 15.6 Mta with new and re-entrants by 2015.

Compared to 11.2 Mta actual installed capacities (2014), consumption is only at 5.47 Mta. This leaves the industry at only 49% capacity utilization rate. Currently, the Ethiopian cement industry is experiencing excess production capacity (about 50% of total installed capacity is operational) consequently, most cement firms are struggling to survive and some small firms have even ceased operation.

However the per capita production as of Cement wise, Ethiopia historically has low cement per capita consumption as low as 39 Kg in 2011 whereas it reached 62 kg in 2014 which is still low compared to the global average of 500 kg/year (Global Cement Magazine 2013, January issue). Furthermore, cement per-capita consumption will be expected grow to 179 kg at the end of 2025 from the current level of 62 kg[2].Cement consumption is rising rapidly due to boom in infrastructure development activity. The government has the intention to raise per capita cement consumption to 300kg and Cement consumption increase 15% every year.

**Table 2.2. Cement Production, Import and Consumption in Ethiopia (In Million Ton**

Year	Domestic Production (Mta)	Import (Mta)	Total Consumption (Mta)
2003/04	1.42	0.00	1.42
2004/05	1.25	0.06	1.31
2005/06	2.75	0.89	3.64
2006/07	1.72	0.85	2.57
2007/08	1.66	1.24	2.90
2008/09	1.69	0.10	1.79
2009/10	1.62	0.49	2.11
2010/11	2.72	0.29	3.01
2011/12	3.77	0.01	3.77
2012/13	4.73	0.00	4.73
2013/14	5.47	0.00	5.48

Source: CSA, CCIIDI, ERCA, ICR, 2014

From literature reviews and documents advised, three issues best explain the abnormal trend in cement apparent consumption as observed in table 2.2. First it shows the level of regulation in the cement market, where the government permits imports in some years and banned in others. The second argument is how much the domestic demand of cement is suppressed; which is implied by the fact that in the years the government permits the importation of cement the quantity demand of cement explodes while in the other years comes to the ending. Lastly, the domestic cement production activity is encircled with many challenges evident by fluctuations in production in the face ever increasing demand of cement in the country.



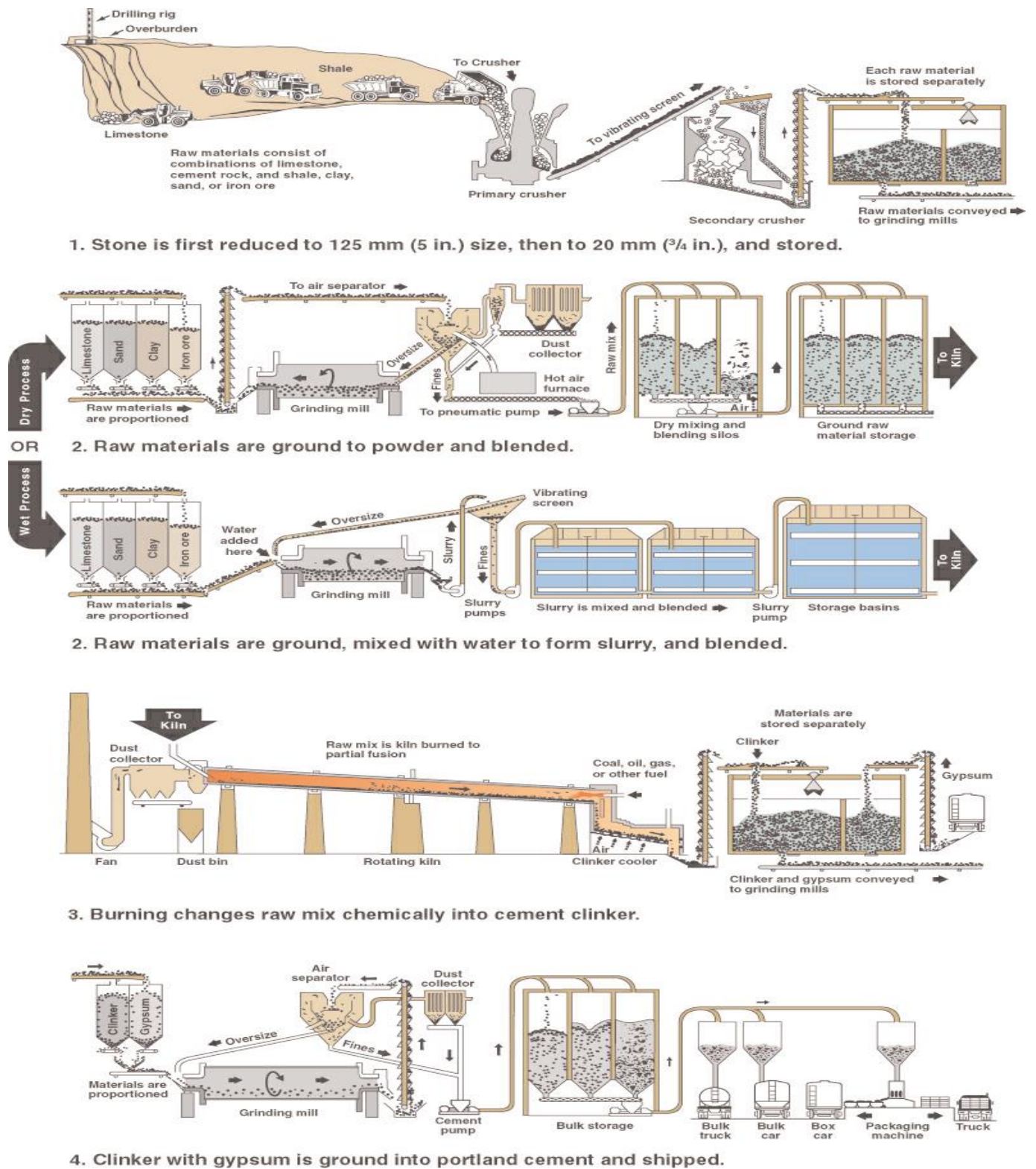


Figure 2-2 Production cycle of Portland cement [Balji kvgd, 2014]

### **2.1.3.2. Effect of Cement production on the Environment**

The cement industry plays a major role in improving living standard all over the world by creating direct employment and providing multiple cascading economic benefits to associated industries.

Despite its popularity and profitability, the cement industry faces many challenges due to environmental concerns and sustainability issues [Potgieter Johannes H, 2014], Potgieter Johannes H, 2014 said that the cement industry is an energy intensive and significant contributor to climate change. The major environment health and safety issues associated with cement production are emissions to air and energy use. Cement manufacturing requires huge amount of non-renewable resources like raw material and fossil fuels. It is estimated that 7-8% of all carbon dioxide greenhouse gases generated by human activities originates from cement production Potgieter Johannes H (2014). Raw material and Energy consumption result in emissions to air which include dust and gases. The exhaust gases from a cement kiln contains are nitrogen oxides ( $\text{NO}_x$ ), carbon dioxide, water, oxygen and small quantities of dust, chlorides, fluorides, sulphur dioxide, carbon monoxide, and still smaller quantities of organic compounds and heavy metals [Marlowe, *et al.*, 2002]. Toxic metals and organic compounds are released when industrial waste is burnt in cement kiln. Other sources of dust emissions include the clinker cooler, crushers, grinders, and materials-handling equipment.

The two major effects of cement production on environments are;

#### **CO<sub>2</sub> emissions during Cement manufacturing process**

Cement manufacturing process releases CO<sub>2</sub> in the atmosphere both directly when calcium carbonate is heated, producing lime and carbon dioxide, and also indirectly through the use of energy if its production involves the emission of CO<sub>2</sub>. The cement industry produces about 7-8% of global man-made CO<sub>2</sub> emissions; half of it comes from producing clinker (the incombustible remains of coal combustion), 40% from burning fuel and 10% from electricity use and transportation [Mahasenan, *et al.*, 2003].

The high proportion of carbon dioxide produced in the chemical reaction leads to a large decrease in mass in the conversion from limestone to cement. So, to reduce the transport of heavier raw materials and to minimize the associated costs, it is more economical for cement plants to be closer to the limestone quarries rather than to the consumer centers.

## **Heavy metal emissions in the air during Cement manufacturing process**

In some circumstances, mainly depending on the origin and the composition of the raw materials used, the high-temperature calcination process of limestone and clay minerals can release in the atmosphere gases and dust rich in volatile heavy metals, the likes of thallium, cadmium and mercury are the most toxic[Balji kvgd,2014]. Heavy metals (Tl, Cd, and Hg) are often found as trace elements in common metal sulphides (pyrite ( $\text{FeS}_2$ ), zinc blende ( $\text{ZnS}$ ), galena ( $\text{PbS}$ ) present as secondary minerals in most of the raw materials. Environmental regulations exist in many countries to limit these emissions. As of 2011 in the United States, cement kilns are "legally allowed to pump more toxins into the air than are hazardous-waste incinerators

## **2.2. Concrete and Its Property**

Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space between the aggregate particles and bind them together. It forms the basis of the modern construction system. The word concrete comes from a Latin word *concretus* which means to grow together Sidney Mindess *et al.*, [2003], which implies that it is a composite of different materials. It is composed of coarse granular material called aggregate or filler which is embedded in a hard matrix of material (cement or binder with water) binding the aggregates together and filling the space formed between them. When the constituents are mixed with water the concrete solidifies and hardens due to a chemical reaction between the water and the cement called hydration, which finally forms a stone like material by binding the aggregates together. Many of our activities directly or indirectly are affected by concrete structures; the buildings we live and work in, the roads we drive on, the dams from which we get water and energy, etc. The ability of concrete to be cast into any desired shapes and configurations is the reason for its versatility. All the constituents have their own purpose in the concrete. Cement with water acts as a binding medium in which the aggregates which accounts 70% to 80% of the concrete are bound together to form the concrete. If a concrete is to be suitable for a particular purpose, it is necessary to select the constituent materials and combine them in such a manner as to develop the special qualities required as economical as possible. Economy, dimensional stability and wear resistance are the main reasons behind using aggregates. Different types of admixtures are used to modify the properties of ordinary concrete so as to make it suitable for any situation. Therefore the selection of constituents of concrete depends on the quality and economy of the particular concrete required.

### **2.2.1. Slump measurements of Concrete**

In general SCBA improve the Consistency and workability of fresh concrete because an additional volume of fines is incorporated in the mixture. It contains in it different aspects like consistency, flow ability, mobility, compact ability, finish ability, and harshness [Sidney Mindess *et al.*, 2003]. This property of concrete is affected by a number of factors like: water content of the mix, mix proportions, aggregate properties, time, temperature, characteristics of the cement and admixtures. Increasing the amount of water will increase the workability of the concrete. However the increase in water content of the mix will decrease the strength and also result in segregation and bleeding.

When considering the effect of aggregate the amount of aggregate, the proportion of coarse and fine aggregate and the shape and texture of the aggregate particles affect the workability of concrete. Keeping the water content and cement content constant increasing the amount of aggregate reduces the workability of concrete

The cement content and cement replacing materials also affect the workability. Higher cement content reduces workability. The effect of cement replacing materials depends on their nature. Finer materials result in reduction of workability while spherical materials increase it.

### **2.2.2. Compressive Strength of Concrete**

Concrete mixtures can be proportioned to produce the required strength and rate of strength gain as required for the application. Nevertheless, strength usually gives an overall picture of the quality of concrete because it is directly related to the structure of the hardened cement paste [Neville, A. M., 1994].

With SCBA other than silica fume, the rate of strength gain might be lower initially, but strength gain continues for a longer period compared to mixtures with only Portland cement, frequently resulting in higher ultimate strength have an effect on the strength of concrete. Strength at any W/C ratio depends on the degree of hydration of the cement and its physical and chemical properties. The decrease in the water content of the concrete results in a higher strength of the concrete. The compaction of the fresh concrete reduces the amount of entrapped air and therefore increases the strength of the concrete. It is found that for each 1 % of air entrapped there will be a 5 to 6 % loss on strength [Abebe Dinku, 2002]. Different pozzolanic materials have different effect on strength.

### **2.2.3. Durability of Concrete**

The ability of the concrete to transmit fluids through it caused by pressure head difference is called permeability of concrete. This property of concrete plays a great role in the durability of the concrete because it controls the entry of moistures which may contain aggressive chemicals and the movement of water during heating and freezing.

Durability of concrete refers to the ability of concrete to resist weathering actions, chemical attacks, abrasions or any processes of deteriorations [Metha, P.K., and Paulo J.M.Monteiro., 2006]. The w/c ratio of concrete has major influence on the permeability of concrete. As the w/c ratio decreases the porosity of the paste decrease and the concrete becomes more impermeable. This variation of permeability with w/c ratio is largely due to large capillary porosity rather than gel pores. Most pozzolanic materials were found to decrease the permeability of concrete due to the pozzolanic reaction and their higher fineness. The pozzolanic reaction consumes the free lime in the concrete and the higher fineness of the pozzolan fills pores in the concrete both resulting in a lower permeability. In a fresh paste the size, shape and concentration of the unhydrated cement particles controls the permeability. As hydration proceeds the permeability decreases rapidly because the gross volume of gel is approximately 2.1 times the volume of unhydrated cement, so that the gel gradually fills some of the original water-filled space [Neville, A. M., 1994]. For cement pastes hydrated to the same degree, the permeability is lower the higher the cement content of the paste.

#### **2.2.3.1. Water to Cement Ratio**

The space initially taken up by water is partially or completely replaced by hydration production as hydration reactions precede. Hydration products are produced by a reaction between cement and water. If the w/c ratio is low, complete hydration is not possible because there is insufficient space for the hydration products. Conversely, if available water exists in cement, hydration will progress continuously and the available space within the paste will be completely filled [Abebe Dinku, 2002]. The heat evolution rate starts to decrease as the w/c ratio decreases after a certain time.

### **2.3. Cementitious (Pozzolans)**

The different types of admixtures in order to enhance the properties of the fresh and hardened concrete, these admixtures can be divided into three main categories, which are cementitious, pozzolanic and non-reactive materials. The first two categories are added at the mixer as supplementary cementing materials interact chemically with the hydrating Portland cement and form a modified paste microstructure.

### 2.3.1. Cementitious (Pozzolans) Content

Pozzolanic materials can be divided into two groups: natural pozzolana and artificial pozzolana. Clay and shales, opalinc chert, diatomaceous earth, and volcanic ash are an example of natural pozzolans while fly ash, blast furnace slag, silica fume, rice husk ash, and metakaoline are example of artificial pozzolans. Therefore classifying pozzolans only depending on their chemical composition would be difficult. For this reason ASTM C 618 classifies pozzolans depending on performance basis. ASTM C 618 chemical composition for pozzolans is as shown in Table 2.3.

Table 2.3ASTM C 618 chemical requirement for Pozzolan [ASTM, part 10, Easton, Md., 1972]

Chemicals	Pozzolan Class		
	N	F	S
SiO <sub>2</sub> +Al <sub>2</sub> O <sub>3</sub> +Fe <sub>2</sub> O <sub>3</sub> (min %)	70.0	70.0	70.0
MgO (max %)	5.0	...	5.0
SO <sub>3</sub> (max %)	4.0	5.0	4.0
Moisture content (max %)	3.0	3.0	3.0
Loss on ignition (max %)	10.0	12.0	10.0
Available alkalis as Na <sub>2</sub> O (max %)	...	1.5	1.5

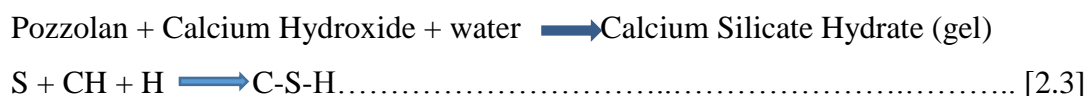
**Note:** N=Natural pozzolana, F=Fly Ash and S= silica fume

The reason behind using pozzolans is the improvement found on both the fresh and hard concrete.

### 2.3.2. The hydration of Cementitious (Pozzolans).

The hydration of tri-calcium silicate and di-calcium silicate with water gives calcium silicate hydrate and calcium hydroxide. The first from have very low solubility in water while the later one is very much soluble in water and has no cementitious value and is found as a free lime in the concrete, resulting in porosity of the concrete, which in turn results in durability problems[Sidney Mindess et al.,2003].

The siliceous and aluminous compounds found in the pozzolan in a finely divided form react with the calcium hydroxide to form highly stable cementitious substances of complex composition involving water, calcium and silica. The principal reaction taking place is as shown in Eq. 2.3 Sidney Mindess et al., [2003]



This reaction is called pozzolanic reaction. The pozzolanic reaction in Eq. 2.3 and its kinetics are more similar to the slow rate of hydration of  $C_2S$  [Sidney Mindess, *et al.*, 2003]. Thus the addition of pozzolans has similar effect with increasing the amount of  $C_2S$ . This results in the reduction of the rate of strength development and the heat of hydration, which makes it advantageous in mass concrete structures.

The progress of hydration of cement can be measured by measuring the amount of Calcium hydroxide in the paste. In a similar manner the extent of pozzolanic reaction can be followed by monitoring the decrease in calcium hydroxide over time.

To get the full benefit of pozzolanic materials moist curing of the concrete is required because of their slow reaction. Without this type of curing the pozzolans simply act as non-cementitious fillers.

## **2.4. Sugarcane Bagasse Ash**

Bagasse ash is one of the biomass sources and valuable byproducts in sugar milling that often uses bagasse as a primary fuel source to supply all the needs of energy to move the plants [Patcharin Worathanakul, *et al.*, 2009]. The use of different cement replacing materials has become a common practice in the construction industry [U.G.Harshali S. Hire<sup>1</sup>, *et al.*, 2017]. Most of these cement replacement materials are byproducts of different industries and agricultural wastes. Example, Blast furnace slag, silica fume, fly ash and rice husk can be sited and Sugarcane bagasse ash has also been found to have such pozzolanic property. The bagasse ash is about 8-10% of the bagasse ash and contains unburned matter, silica and alumina [Ajay Goyal, *et al.*, 2007], which is a problem to the environment due to its disposal. Therefore, due to lack of research most of the bagasse ash is disposed in the landfills [Chusilp, N.,*et al.*, 2009] and only a few studies reported the use of bagasse ash as partial replacement of cement in concrete [Ganesan, K.,*et al.*,2007]. Since, there is a continuous increase in the production of sugar worldwide and approximately 1500 Million tons of sugar cane are annually produced all over the world, which leaves about 40-45% bagasse after juice extraction [Ajay Goyal *et al.* 2007], Therefore, by taking 40% an average annual production bagasse ash is estimated as 600 Million tons, which is a bulky waste from sugar industry

### **2.4.1. Properties of Bagasse Ash as cementitious Material**

Pozzolans are siliceous or aluminous materials which alone possess little or no cementitious value but which will, in finely divided form in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties [G. Nithin Kumar Reddy *et al.*,2014]. Bagasse ash also acts as a pozzolanic material when added to cement

because of its silica ( $\text{SiO}_2$ ) content which reacts with free lime released during the hydration of the cement and forms additional calcium silicate hydrate (CSH) as a new hydration product [Bangar Sayali, *et al.*, 2017]. This additional CSH improves the mechanical strength of the cement mortar and concrete.

The Pozzolanic activity of a bagasse ash primarily depends on two factors:

- The amount of calcium hydroxide available for the reaction with the bagasse ash.
- The reaction rate that this combination occurs, which is dependent on Temperature.

The amount of available calcium hydroxide depends on the chemical properties of the bagasse ash used, the nature of its active phase, the content of  $\text{SiO}_2$  in the active Pozzolana and the  $\text{Ca}(\text{OH})_2$  to bagasse ash ratio in the mixture.

The reaction rate depends on physical factors, such as the surface area of bagasse ash particles, the solid to water ratio of the mixture and the temperature. When amorphous silica comes into contact with water, it solubilizes into an alkaline solution and reacts with  $\text{Ca}^{+2}$  ions, forming hydrated calcium silicates similar to those produced through cement hydration reactions. The large number of various size of pores with irregular and heterogeneous shapes were observed which contributed to the surface area of adsorbent (Jemal Fito., *et al.*, 2017). This remarkably rough and pores containing surface revealed that the material is providing the binding sites for concrete.

#### **2.4.2. The uses of Bagasse Ash as Cement Replacing Material**

Bagasse ash has numerous technical and other non-technical advantages to the user when it is used as a partial replacement of cement. These days sustainability plays the major role in every aspect of human activities. Concrete being one of the most widely used materials worldwide next to water, is not free from some negative environmental impacts [Meyer C., 2007]. Its popularity carries with it a great cost in terms of environmental aspects. Environmental problems associated with concrete can have varied origins.

One of the constituent which causes the largest environmental impact is Portland cement. The reduction of Portland cement in concrete can be achieved by replacing it with different supplementary cementitious materials which are a byproduct of another industry.

#### **2.4.3. Currently potential of Bagasse ash in Ethiopia**

In order to assess the potential of bagasse ash production in Ethiopia, it is imperative to evaluate the sugarcane crop yield in the country. Ethiopia began investment in sugar industry in 1954 with one sugar factory which have been expanded to four small size sugar factories up to 1998.



By recognizing the nature of the industry, the Ethiopian Government established Ethiopian Sugar Corporation (ESC) in November, 2011 in order to complete the projects commenced by the Agency and embark on the expansion of new sugar projects.

The total area developed by these factories is 305,200 hectares. The area developed at Wonji Shewa is 17,000 hectares capable of producing 225,000tons of sugar per annum. The Metehara Sugar Factory, which was brought on stream in 1969 at Metehara, developed 10,200 hectares and has a capacity to process 130,000tons of sugar annually. The Finchaa Sugar Factory (in East Wellega zone of the Oromia National Regional State) which was completed in 1998 developed 21,000 hectares and has a production capacity of 266,000tons of sugar per annum.

Tendaho Sugar Factory developed total Cane Plantation Currently 18,900 Ha -50,000 Ha, First Phase Finalized On Sept. 2014/15, has a capacity to process (258,000 Ton of Sugar) and Second Phase (618,000 Ton of Sugar) annually.

This annual production is not sufficient to satisfy the local sugar demand forcing the government to annually import 1.5 million quintals from abroad [The Ethiopian Sugar Industry *Current Status & Future Prospect* on the 23rd ISO Seminar Nov.2014]. Fill the gap between supply and demand of sugar, Ethiopian Sugar Corporation has set a strategic plan to build ten new sugar factories at different locations of the country.

ESC started the development of additional 10 big size sugar projects by expanding the factory sites from 5 location to 9 location which is distributed all over the country. And the number of industries from 4 to more than 14 When these and the existing facilities are up and running, the ESC is predicting that the country will become one of the ten largest sugar producers by 2023, with production estimated 4.2 million metric tons. However, to crack the list of today's top 10 sugar (cane + beet sugar) producers, Ethiopia would have to produce more than 4.5 million metric tons. In comparison, when comparing Ethiopia against cane sugar producers, Ethiopia would be the 8<sup>th</sup> largest producer after Australia (4.8 MMT) and before the United States (3.3MMT). Beside this the Ethiopia government is undertaking expansion projects on the existing factories to increase their production capacity. At the end of this expansion projects on Fincha, Methara and Wonji/Shoa sugar factories the additional (not including the current production) total aggregate production capacity is expected to be around 365,000 tons of sugar annually [Ethiopia plans to take 2.5pc of the world sugar market, 2010]. As can be seen from the above discussion the sugar production in the country is being boosted at a high rate, even planning to hold 2.5 percent of the world sugar market in the coming five years according to the strategic plan.

Boosting sugar production will also result in high amount of bagasse and bagasse ash. Table 2.4 below summarizes the expected future sugar production of the country and the respective bagasse ash potential.

Table 2.4. Estimated bagasse ash potential of Ethiopia

Factory	Expected future Production of sugar(tons/year)	Estimated Bagasse (tons/year)	Estimated Bagasse Ash (tons/year)
Wonji/ Shoa	220,700	662,100	52,968
Metahara	136,692	410,076	32,806
Finchaa	270,000	810,000	64,800
Tendaho	876,000	2,628,000	210,240
New 10	3,173,400	9,520,200	761,616
<b>Total</b>	<b>4,676,792</b>	<b>14,030,376</b>	<b>1,122,430</b>

The above estimation is based on the targeted annual future sugar production in the country. Sugarcane consists of about 30% bagasse whereas sugar recovered is about 10% of the sugarcane, the bagasse leaves about 8-10% (8% taken for the calculation) bagasse ash as waste [Ajay Goyal et al., 2007 and Noor Ul Amin, 2010]. As can be seen from Table 2.4 about 1.12 million tons of bagasse ash is going to be generated annually when the five-year strategic plan comes into reality. Currently with sugar production of about 350,000 tons annually, the bagasse ash potential is about 84,000 tons annually. According to the Growth Transformation Plan (GTP) of Ethiopia, 4.6 Million Tons of sugar is expected to be produced every year and results the production of 1,104,000 tons of sugar cane bagasse ash as a waste annually. This amount of waste product can be useful if it is used for different productive purposes. From those one is using it as a supplementary cementitious material in concrete production.

Since the construction industry is booming in the country, the demand of cement and aggregates are become more essential [Ethiopia plans to take 2.5pc of the world sugar market, 2010] In this situation using of other waste material that has potential as cement is advantageous and also selling bagasse ash to other countries may become one source of getting additional foreign currency.

## **2.5. Selected Approach for Method**

The selected approach to optimizing the bagasse ash to cement mix proportions of concrete is based on the planned experimental works (within the domain of required characteristic performance of concrete) and statistical analysis of the data generated, which would reduce the number of trial batches needed. The selected approach consists of the following steps.

### **2.5.1. Selecting of Specification and Characteristic of Concrete**

The information pertaining to required workability, strength, and exposure conditions (for durability requirements) should be first collected. The workability requirements depend on the mode of transportation, handling, and placing and also on type of construction [American Concrete Institute, 2009]. The strength is specified based on the structural requirements for concrete protected from exposure to freezing substances and environmental changes. However, the strength specified by the structural designer should not be less than the minimum design compressive strength recommended for the given condition. The durability requirements of concrete mixtures are normally satisfied by ensuring that the cementitious materials content is not less than a specified minimum value and the w/cm materials ratio is not more than the one specified for a given exposure condition. For example, the cementitious materials content should not be less than 335 kg/m<sup>3</sup> and water/cementitious materials ratio should not be more than 0.45 (by mass) for satisfying the durability requirements for concrete subjected to weather conditions such as severe freeze-thaw, deicer, and sulfate exposures [American Concrete Institute, 2008].

### **2.5.2. Selection of Levels for Mix Design Factors.**

Selected of levels for mix design Factors contain three key bagasse ash to cement mix proportion design factors, namely, cementitious materials content, water/cementitious materials ratio, and fine/total aggregate ratio, which mainly affect the quality of concrete will be made to ensure that enough experimental data are generated for obtaining a regression model for compressive strength which can be used to optimize the mix proportions meeting the specified characteristic performance of concrete.

### **2.5.3. Experimental Work to Obtain Statistical Model for Optimization.**

An experimental work should be conducted involving designing, preparing, and testing various trial mixtures according to the full factorial experiment design considering the various possible combinations of the levels of the mixture variables within their selected ranges of variation.

After finalizing the based on the required workability for each of the trial mixtures, the cubical specimens should be prepared, cured for 28 days, and then tested for compressive strength for generating data to obtain statistical model for strength to be used for optimization.

#### **2.5.4. Statistical Analysis of Experimental Data and Fitting of the Strength Model**

Analysis of variance (ANOVA) can be used for examining the significance of the factors considered for developing the strength model and subsequently fitting an empirical model for compressive strength in terms of the significant mixture factors using polynomial regression [Douglas C. Montgomery, 2001]. In ANOVA, the statistical terminologies used are as follows.

***Degree of Freedom (DF)*** Degree of freedoms the number of values in the final calculation of a statistic that are free to vary  $DF = n - 1$ , where  $n$  represents the number of groups.

***Error (Residual)***: It is the amount by which an observed variant differs from the value predicted by the assumed statistical model.

***Sum of Squares (SS)***: It is the squared distance between each data point ( $X_i$ ) and the sample mean ( $\bar{X}$ ), summed for all  $n$  data points.  $SS = \sum_{i=1}^n (X_i - \bar{x})^2$  where,  $X_i$  represents the  $i^{\text{th}}$  observation and  $\bar{x}$  represents the sample mean.

***Mean Square (MS)***: It is the sum of squares divided by the degrees of freedom.

***F-Ratio***: It is ratio of MS of the concerned factor to the MS of the error. A higher  $F$ -ratio indicates a significant effect of the factor.

***P-Value***: It is a measure of *acceptance* or *rejection* of a statistical significance of a factor based on a standard that no more than 5% (0.05) level of the difference is due to chance or sampling error. In other words, if the  $P$ -value for a factor is 0.05 or more, it would not have effect on the dependent variable.

#### **2.5.5. Optimization of BA/OPC Mix Proportion Using the Fitted Strength Model**

The statistical model for the compressive strength derived utilizing the experimental model can be used to obtain the optimal mixture proportions satisfying the specified characteristic performance of concrete as required constraints. The mixture satisfying all the constraints and having the lowest requirements of cement and bagasse ash to cement mix would be considered as optimum mixture.

### **3. MATERIALS AND METHODS**

#### **3.1. MATERIALS**

In this part, the materials used for input experiments are described with respect to their source and relevant physical and chemical properties.

##### **3.1.1. Binder (Cement)**

Locally available ordinary Portland cement used when reacts with water hardened to form a rigid chemical mineral structure which holds the aggregates together gives concrete strengths thus Ordinary Portland cement is selected over other cements. Because of early stripping, optimum mechanical properties, high-grade and early strength cement are recommended. Then the selected cements to meet the specified requirements for concrete is Dangote cements, that Located 87km from Addis Ababa in West Shoa zone, District Ada-berga. These cements available at markets were purchased from the shops found in Addis Ababa and comply with the requirements of Ethiopian Standards, ES C.D5 201 and ES C.D5 202 [Esayas G.youhannes (Ph.D), Getu Berhanu (Eng.), 2017].The cement was stored in dry place and away from moisture to ensure in good condition during the experimental period.

##### **3.1.2. Sugarcane Bagasse Ash**

The bagasse ash used for this research was taken from Wonji/ Shoa Sugar factory which is located in Oromia Regional State North Eastern Ethiopia about 110 Km from the capital city Addis Ababa. The burning of bagasse leaves bagasse ash as a waste, consists mainly of silica ( $\text{SiO}_2$ ), [Payá, J., et. al., 2007], which indicates its potential as mineral admixture for use in concrete as a pozzolan and which has a pozzolanic property that used as bagasse ash to cement mix proportion cementitious material replace of cement. For this research, fresh bagasse ash collected from a dump around the Wonji/ Shoa sugar factory then cooled and packed in sacks then transported to Addis Ababa.

##### **3.1.3. Aggregates**

Aggregates should be free from impurities like silt, clay, dirt and organic matter.

Soft, porous rock can limit strength and wear resistance; it may also break down during mixing and adversely affect workability by increasing the amount of fines.

#### **3.1.4. Water**

In this research, water supplied by Addis Ababa Water and Sewerage Authority found in the laboratory was used in all mixing and curing. Potable water was generally considered satisfactory for concrete mixing and curing PH value shall not be less than 6 is conformed to the required of water for concreting and curing.

#### **3.1.5. Controlled Experimental Parameters**

The Workability, strength and durability of concrete was normally governed by such factors as cementitious content (BA/OPC ratio), Water-cement ratio, and fine aggregate/total aggregate ratio.

**Cement/bagasse ash ratio:** - Different pozzolanic materials have different effect on strength. But most of them including bagasse ash have been found to improve the strength of concrete especially at 28 days due to the reaction. The minimum level of cementitious materials content should not be less than 335 kg/m<sup>3</sup> which is the minimum value to satisfy the durability requirements for aggressive exposure conditions. The maximum level of cementitious materials content selected considering the risk of shrinkage.

**Water-cement ratio:** - Strength at any W/C ratio depends on the degree of hydration of the cement and its physical and chemical properties. The decrease in the water content of the concrete results in a higher strength of the concrete. The water required for the hydration reaction was less than that of the mixing water; the extra water provided was used to make the concrete more workable. The minimum level of water/cementitious materials ratio was selected considering the strength requirements. In case of choosing a very low level of the water/cementitious materials ratio, the difficulty in transporting, handling, and placing concrete and extra cost of superplasticizer to meet the workability requirements should be considered. The maximum level of the water/cementitious materials ratio was within the maximum permissible limit for the water/cementitious materials ratio for the given exposure condition.

**Fine aggregate/coarse aggregate ratio:** In general, aggregates are hard and strong, free of undesirable impurities, and chemically stable. Soft, porous rock can limit strength and wear resistance; it may also break down during mixing and adversely affect workability by increasing the amount of fines. Aggregates should also be free from impurities: silt, clay, dirt or organic matter. The minimum and maximum levels of the fine/total aggregate ratio should be selected within the optimum range for achieving maximum packing of aggregates.

### **3.2. Apparatus Used For Experiments**

#### **3.2.1. Apparatus used to determine of coarse and fine aggregates quality.**

The apparatus used for test fineness modulo us, Moisture Content, Void content, Specific Gravity and Absorption, Bulk Specific Gravity(SSD), Apparent Specific gravity, Unit weight of coarse and fine aggregates are: Set of standard sieves, Digital weighing balance, Sieve shaker, Tray riffle box, a balance sensitive to 0.5gm, Electrical oven at temperature 105 °C, Container with a cover, Sample splitter, Sample container (A wire basket) [20cm diameter& 20cm in height], Water tank; a watertight tank into which the sample container may be placed while suspended below the balance, Sieves; 4.75mm (No.4) or other sizes as needed arranged one above the other with the sieve size increasing from the top and pan was put at the bottom.

A balance having capacity of 1kg or more sensitive to 0.1gm, Pycnometer a flask or other suitable containers are used for purpose of determine coarse and fine aggregate material quality.

#### **3.2.2. Apparatus used for fineness of cement and bagasse ash test.**

The apparatus used for measure degree of fineness of the mean size of the grains in the cement are: 90 $\mu$  sieve, Tray, Digital weighing balance and Blaine's variable flow air permeability apparatus.

#### **3.2.3. Apparatus used for normal Consistency test of cement and blended pasties**

The apparatus used for test standard consistency of cement are: Vicat apparatus with the plunger end 10 mm in diameter, Tray, Trowel, Measuring cylinder (200 or 250) ml capacity, Weighing machine, containers and mixing glass plate 30cm x 30cm.

#### **3.2.4. Apparatus used for initial and final setting time of cement and blended pasties.**

The apparatus used for test initial and final setting time of cement and blended pasties are: Vicat Apparatus with the needle end, 1mm in diameter, Glass Graduates (200 or 250) ml capacity, Weights and weighing Device, A trowel and containers.

#### **3.2.5. Apparatus used soundness of given cements and blended pasties.**

Le Chatelier apparatus - It consists of a small split cylinder of spring brass of 0.5 mm thickness, forming a mould 30mm internal diameter and 30mm high. On either side of the split are attached two indicators with pointed ends the distance from these ends to the center of the cylinder being 165mm. The mould shall be kept in good condition with the jaws more than 0.5mm apart, Tray, Measuring Flask, Digital Weighing Balance, piece of glass sheet and Scale Water Bath.

### **3.2.6. Apparatus used to determine of fresh concrete workability.**

The apparatus used to determine the slump of freshly mixed concrete, which is measure of consistency that test done in the laboratory are:

Weights and weighing device, Tools and containers for mixing, or concrete mixer, Tamper ( 16 mm in diameter and 600 mm length), Ruler, Slump cone which has the shape of a frustum of a cone with the following dimensions, Base diameter 20 cm, Top diameter 10 cm, Height 30 cm and flat mixing pan.

### **3.2.7. Apparatus used to determine compressive strength of concrete.**

The apparatus covers determination of compressive strength of cubic concrete specimens tests are:

Weights and weighing device, tools and containers for mixing, power mixer, tamper (square in cross section), three cubes (150 mm side), trowel, water basin and testing machine.



### **3.3. Methods**

The main objective of the test program was to study the optimization of bagasse ash to cement mix and suitability of bagasse ash as a cement replacing material. These include studying properties of paste and concrete works by replacing part of the cement with bagasse ash in different percentages.

Three major tests were conducted in order to achieve these objectives. The first experiment was done on identify the properties of the aggregates, The second experiments was done on blended powders and pastes in which part of the cement was replaced by bagasse ash in order to determine the fineness of the blended powder, the water requirement or normal consistency, setting time of the blended paste and soundness of the blended paste. The third experiments were made on concrete in which part of the cement was replaced by bagasse ash.

These tests were used to investigate the pozzolanic property of bagasse ash, its effect on the performance of the concrete such as workability, strength and durability Statistical methods also require a certain amount of experimental works but they have an additional advantage in a sense that the expected properties (responses) can be characterized by an uncertainty (variability).

In the present work, an effort has been made to exhibit the application of a statistical approach proposed to obtain optimum proportioning of concrete mixtures using the data obtained through an experiment design considering water-cementitious materials ratio, cementitious materials content, and fine aggregate to total aggregate ratio as design factors.

The experimental data were analyzed statistically and mathematical polynomials regression was developed for concrete strength as a function of mixture variables. The utility of the developed compressive strength model in optimizing the mixture was illustrated considering different possible options.

#### **3. 3.1. Experiments for investigating Properties of Aggregates**

The relevant tests were made to identify the properties of the aggregates which are used for this research. After that, corrective measures were taken in advance before proceeding to the mix proportioning, like blending the aggregates in order to meet the grading requirement, washing the aggregates in order to meet the standard for the silt content.

### **3.3.1.1. Properties of the coarse aggregate**

Aggregates predominately retained on sieve Number 4 (4.75mm) are classified as coarse aggregate. The aggregate used for this research is basaltic crushed rock which is strong and hard. A maximum aggregate size of 25 mm was used in all the concrete work. After washing and drying, the coarse aggregates were sieved and stored. This has minimized segregation and thus variation in gradation from mix to mix.

### **3.3.1.2. Properties of fine aggregate**

The fine aggregate used as in put for concrete productions is natural sand. In order to investigate its properties for the required application different tests were carried out which include: sieve analysis and fineness modules, specific gravity and absorption capacity, moisture content, silt content and unit weight. Oven dried aggregate sample is used in this test [Abebe Dinku, 2002]

## **3. 3.2. Experiments for investigating Fineness of bagasse ash to cement Blended and Pastes**

This experiment consists of determining the fineness of blended powders and pastes in which part of the bagasse ash to cement was replaced by bagasse ash in order to determine the fineness of the blended powder, the water requirement or normal consistency, setting time of the blended paste and soundness of the blended pastes.

### **3.3.2.1. Physical and Chemical properties of Bagasse Ash**

The grinding of the ash was done in Addis Ababa Science and Technology University Food science Department laboratory using a small mill having a capacity of carrying about 100gm of bagasse ash at a time and then the bagasse ash size was reduced to fineness similar to that of Portland cement. After reduced the ash size, it was taken to the Geological Survey center of Ethiopia for the complete silicate analysis and for major chemical composition of bagasse ash that related major chemical composition of cements.

### **3.3.2.2. Fineness Test of Cement, Bagasse Ash and the Blended Powders**

The fineness of the cement, the bagasse ash and the blended powders at different percentage were determined by the blain air permeability method.

### **Air Permeability Method (Blaine Method)**

The method is comparative rather than absolute known specific surface is required for calibration of the apparatus.

#### **Calibrations of Blaine Apparatus are:**

Calculate the volume of the compacted bed of cement C by the formula  $C = (W1 - W2)/P$

Where W 1= mass of the mercury required to fill the permeability cell

W2=mass of the mercury to fill the portion of the cell not occupied by the bed of cement formed by 2.84 gm of standard cement sample.

P = Density of mercury at the temperature of test.

The masses W1 and W2 are obtained by weighing the mercury in the crucible.

Evacuate the air until the fluid moves above the upper line without pulling it over the top of the side outlet close the valve and note the time  $T_s$  taken by manometer liquid to fall from 2<sup>nd</sup> mark (from top) to the 3<sup>rd</sup> mark on the manometer when the air allowed to permeate through the compacted bed of standard cement sample. Note the air temperature

#### **3.3.2.3. Water Content (normal consistency) test**

ASTM C 595 recommends the normal consistency test of blended cements to be measured by the ASTM C 187 method, which is the method for that of hydraulic cement. Therefore, the normal consistency was measured by a vicat apparatus. The procedure used for this test is as described in ASTM C 187 and apparatus used in this research work. Different pastes both control i.e. without bagasse ash and blended were prepared by replacing part of the Portland cement with bagasse ash.

#### **Procedures followed during Normal Consistency test**

400 gm of cement is taken; a percentage (p) of water by weight is added with water.

Add the cement to the water and allow 30s for absorption of the water.

Water and cement is mixed thoroughly on a non-porous surface.

The mould of Vicat apparatus is filled with the paste and made the surface smooth and level by trowel.

The plunger A is attached to the moveable rod of Vicat apparatus.

The plunger is gently lowered over the cement and blended paste & released quickly.

The penetration is between 5mm to 7mm or  $10 \pm 1$  mm from the bottom of the mould, the water added is correct.

#### **3.3.2.4. Measuring Setting Time**

ASTM C 595 recommends the use of ASTM C 191 method of measuring setting time, which is used for that of hydraulic cements. The initial setting time of the paste was determined by the duration of 25mm penetration of vicat needle into the paste in 30 seconds after it has been released while the final setting time was determined by measuring the time related to zero penetration of the needle into the paste.

##### **Procedures followed during setting time test are:**

Weigh (400) gm cement and 5%, 10% and 15% blended bagasse ash.

Prepare amount of water as to that calculated in normal consistency test.

Prepare cement and blended bagasse ash paste following same steps mentioned in normal consistency test.

Place in Vicat conical ring. Then record the time since the cement is added to the water.

Allow the time of setting specimen to remain in the moist cabinet for 30 minutes after molding without being disturbed.

Determine the Penetration of the 1mm needle at this time and every (30) minutes until a penetration of 25mm or less is obtained

Then read the penetration, lower the needle of Vicat Apparatus until it touches the surface of the cement paste. Tighten the screw and take an initial reading. Release the set screw and allow the needle to settle for 30 seconds, and then take the reading to determine the penetration.

Record the results of all penetration, then by interpolating determine the time when a penetration of 25 mm is obtained. This is the initial setting time. But, the final setting time is when the needle dose not sinks visible into the paste.

#### **3.3.2.5. Soundness test**

Soundness test conducted by using the Le Chatelier apparatus which consists of a small brass cylinder split, the cylinder (which is open on both ends) is placed on a glass plate filled with cement paste of normal consistency, and covered with another glass plate. The whole assembly is then immersed in water at  $27 \pm 2^{\circ}\text{C}$  for 24 hours. At the end of that period the distance between the indicator points is measured. The mould is then immersed in water again and brought to a boil. After boiling for 30 min the mould is removed from the water, after cooling, the distance between the indicator points is measured again. This increase represents the expansion of the cement paste for Portland cements; expansion is limited to 10mm

**Procedures followed during soundness test are:**

First of all the mould is placed on a glass sheet and filled with cement paste formed by gauging cement with 0.78 times the water required to give a paste of normal consistency.

The mould is then covered with another piece of glass sheet, a small weight is placed on this covering glass sheet and the assembly is immediately submerged in water at a temperature of  $27 \pm 2^\circ\text{C}$  and kept there for 24 hours.

The distance separating the indicator points is measured and the mould was again submerged in water at the temperature prescribed above.

The water is then brought to boiling, with mould kept submerged for 25 to 30 minutes, and is kept there for three hours.

The mould is removed from water, allowed to cool and the distance between the indicator points is measured. The difference between these two measurements is found and reported as the expansion of cement and blended of pasties.

**3.3.3. Experiments for investigating Properties of concretes**

For illustrating the utilization of the selected approach to optimizing Bagasse Ash to Cement Mix Proportion for M30 Grade Concrete, an experimental program was considered. A full factorial experiment with  $3 \times 3 \times 3$  treatment combinations was used resulting in a total of 27 concrete trial mixes considering three typical levels of each of the three key factors affecting the performance of concrete mixtures. Water content = 159.12 lit, 179.0lit and 198.9 lit

Total Cementitious materials BA/OPC, by mass = 397.8kg

FA=598.78kg, 729.5kg and 870.075kg

CA=1105 kg constant at all level

TA=1703.78kg, 1834.5kg and 1975.075kg from this the three key factors in Table 3. 1For the levels of the water/cementitious materials ratio selected in the present work, no super plasticizer was added.

Table 3. 1. The three factors of bagasse ash to cement mix and levels of the ratio selected were

<b>Factor</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>Level</b>
Cementitious materials content (BA/OPC by mass)	5/95= <b>0.05</b>	10/90= <b>0.1</b>	15/85= <b>0.15</b>	3
Water/cementitious materials ratio by mass	159.12/397.8= <b>0.4</b>	179.01/397.8= <b>0.45</b>	198.9/397.8= <b>0.5</b>	3
Fine/Total aggregate ratio by mass	598.78/1703.78= <b>0.35</b>	729.5/1834.5= <b>0.4</b>	870.075/1975.075= <b>0.45</b>	3

### 3.3.3.1. Bagasse ash to cement mix design and trial mix preparation

In these mixes the performance of the concrete is specified by the design but the mix proportions are determined by the produce of concrete. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics of M30 grade mix proportion. In this designation the letter M refers to the mix and the number 30 to the specified 28 day cube strength of mix in N/mm<sup>2</sup>. The mixes of grades M30 correspond approximately to the mix proportions (1:1.8:2.8) respectively for control concrete, the mix contains 1 part of cement, 1.8 parts of fine aggregate and 2.8 parts of coarse aggregate proportions by mass.

Minitab 18 method of mix design was used in designing the mixes. The trial mix was prepared for characteristics strength of 30MPa with water to cement ratio of 0.45 and a cement content of 397.8kg/m<sup>3</sup>. Taking 1.5 as the extrapolation factor, the 28 days compressive strength would be around 37.65MPa which is slightly higher than the targeted value.

For the purpose of preparing a final mix the water to cement ratio of the mix was increased from 0.40 and 0.45 to 0.5 by keeping the cement content constant i.e. water increased from 179kg/m<sup>3</sup> to 198.9kg/m<sup>3</sup>, in order to adjust the slump. [Sidney Mindess *et al.*, 2003] suggested that an increase or decrease of the water content by 6kg/m<sup>3</sup> will increase or decrease the slump by approximately 25mm. The proportioning of all 27 trial mixtures was carried out in terms of absolute volume using the specific gravities of the concrete ingredients and the values of water/cementitious materials ratio, cementitious materials content, and Fine/ Total aggregate ratio for each of 27 mixtures, the final mix proportions for 1m<sup>3</sup> of the different control and BA /OPC concretes are shown in Table 3.2 was the experimental program consists of preparing different concrete mixes with different percentage of bagasse ash in order to study the performance of the concrete such as its workability, compressive strength and durability.

Table3.2. Trial of bagasse ash to cement mix proportion

Mix number	Water/cementitious materials ratio by mass	Cementitious materials BA/OPC, by mass	Fine/ Total aggregate ratio by mass
control	0.45	0	0.45
1	0.40	0.053	0.350
2	0.40	0.053	0.400
3	0.40	0.053	0.450
4	0.40	0.111	0.350
5	0.40	0.111	0.400
6	0.40	0.111	0.450
7	0.40	0.176	0.350
8	0.40	0.176	0.400
9	0.40	0.176	0.450
10	0.45	0.053	0.350
11	0.45	0.053	0.400
12	0.45	0.053	0.450
13	0.45	0.111	0.350
14	0.45	0.111	0.400
15	0.45	0.111	0.450
16	0.45	0.176	0.350
17	0.45	0.176	0.400
18	0.45	0.176	0.450
19	0.50	0.053	0.350
20	0.50	0.053	0.400
21	0.50	0.053	0.450
22	0.50	0.111	0.350
23	0.50	0.111	0.400
24	0.50	0.111	0.450
25	0.50	0.176	0.350
26	0.50	0.176	0.400
27	0.50	0.176	0.450

**N.B:** 0.053=19.89/377.91 where, 19.89kg is **BA** by mass of 5% and 377.91kg **OPC** by mass of 95%

0.111=39.78/358.02 39.78kg is **BA** by mass of 10% and 358.02kg **OPC** by mass of 90%

0.176=59.67/338.13 59.67kg is **BA** by mass of 15% and 338.13kg **OPC** by mass of 85%

### **3.3.3.2. Preparation of concrete specimens and mixing procedure.**

Making and curing concrete test specimens in lab was carried out according to ASTM C192. The experiments was designed by using mini tab 18 apply for the experimental design of optimization of bagasse ash to cement mix proportion for M30 grade concrete before production by considering the proportion limits according to American concrete institution (ACI) guidelines. Considering three replicates for each of the 27 mixtures, a total number of 81 cubical concrete were cast for determining compressive strength. Weight measurement was used for the preparation of the constituent.

#### **Procedures followed during slump cone test are:**

Prepared a clean wide flat mixing pan then Place the dampened slump cone on one side of the pan. It shall be held firmly in place during filling by the operator standing on the two foot pieces.

Place the newly mixed concrete prepared for test in three layers, each approximately one third the volume of the mold.

Rod each layer with 25 strokes of the tamper, distribute the strokes in a uniform manner over the cross section of the mold, each stroke just penetrating into the underlying layer.

For the bottom layer this will necessitate inclining the rod slightly and making approximately half of the strokes spirally toward the center rod the bottom layer throughout its depth.

In filling and rodding the top layer, heap the concrete above the mold before rodding is started.

Measure the slump immediately by determining the difference between the height of the mold and the height of the vertical axis (not the maximum height) of the specimen.

### **3.3.3.3. Concrete Curing and Testing**

The specimens should be stored in moist air for 24hours and the specimens are remove from the mould after 24hr should be marked and submerged in clear fresh water until the specimens are take out from the curing tank just prior to the test, the concrete should be surface dry for two hours to be tested in the moist condition.

The average compressive strength of the three specimens the same concrete mixture tested at the same age and considered as characteristic compressive strength of a mixture. The concrete was surface dried for two hours to be tested in the moist condition according to ASTM C39 and measure its mass weight then compressive strength test was conducted using compression testing machine with a loading rate of 6.8kN/sec and capacity of 3000kN. Average 28-day compressive strength test results for all 27 concrete mixtures along with the standard deviation of three replicates of each mixture of concrete block should be noted and evaluate test results and discuss.



## **4. RESULTS AND DISCUSSION**

The discussion and analysis of laboratory results of physical properties of the coarse aggregate and the fine aggregate, bagasse ash to Cement Mix for its suitability as supplemented cement material are presented and investigated are:

- ❖ The physical properties of the coarse aggregate and the fine aggregate
- ❖ The fineness in terms of specific surface area for different bagasse ash to cement mixes
- ❖ The consistency and setting time of the blended pastes at different replacement contents,
- ❖ The soundness of cement and blended pastes at different replacement contents,
- ❖ Workability containing bagasse ash which replaced ordinary Portland cement and
- ❖ The compressive strength and durability of concrete containing bagasse ash.

### **4.1. Results and discussions on Properties of Aggregates**

In this part the test results on the different properties of particle size distribution of the aggregate are discussed and analyzed

#### **4.1.1. Physical Properties of the aggregate**

This is a procedure for the determination of the particle size distribution of the aggregate. It is also used to determine the fineness modulus, coarseness and uniformity of aggregates. These aggregate properties greatly affect the property of the concrete.

##### **4.1.1.1. Sieve Analysis and fineness modules of coarse aggregate**

The laboratory tests were carried out to identify the physical properties of the coarse aggregate. Aggregates contain pores in their structure, therefore the specific gravity depends on whether the pores are included in the measurement or not and the sieve analysis test results are shown in Table 4.1 below.

Table 4.1. Sieve analysis for coarse aggregate

Sieve Size, in (mm)	Mass Retained, (g)	% Retained	% Passed	Determination (%) passing ASTM C33
63	0.00	0.00	100.00	
50	0.00	0.00	100.00	
37.5	0.00	0.00	100.00	100
25	554.00	27.7	72.30	90-100
19	690.00	34.5	37.80	40-85
12.5	569.00	28.45	9.35	10-40
9.5	135.00	6.75	2.60	0-15
4.75	43.00	2.15	0.45	0-5
PASS	9.00	0.45	0.00	
<b>Total</b>	<b>2000.00</b>			

The graph for the sieve analysis of the coarse aggregate and the standard (ASTM C33) is as shown in Figure 4.1;

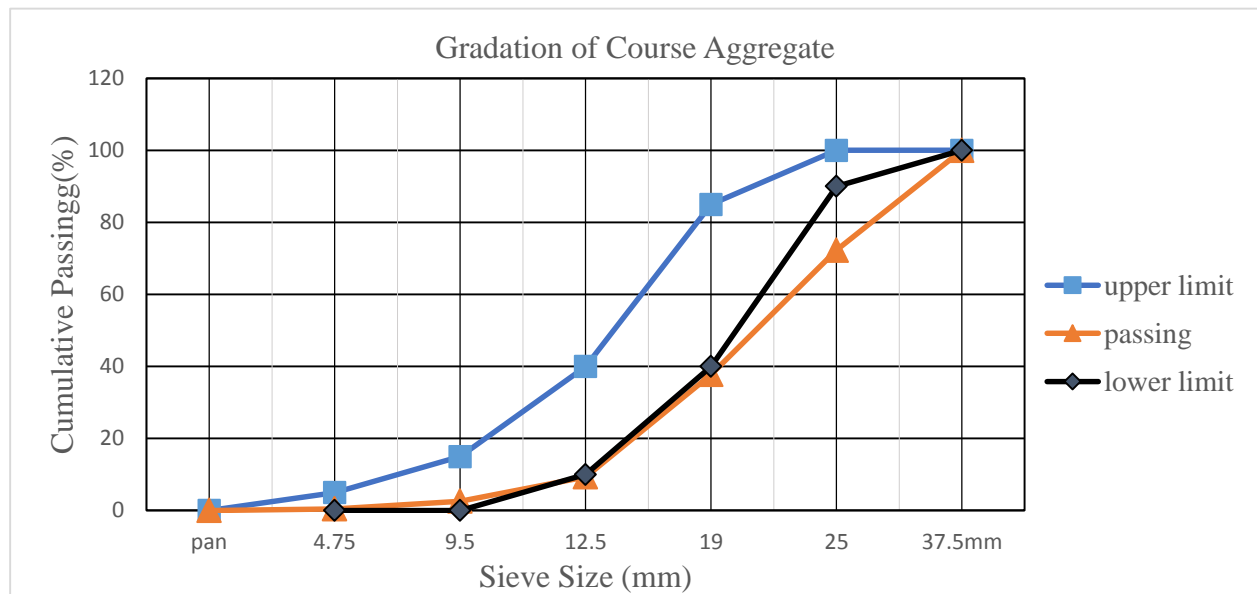


Figure 4.1. Graph for gradation of coarse aggregate

### Moisture content of coarse aggregate

Weight of Saturated surface dry test samples in air (B) = 2000g

Weight of Saturated surface dry test samples in Water (C) = 1314.9g

Weight of oven dry sample in air (A) = 1975.38g

$$\begin{aligned}\text{Moisture content} &= ((B-A)/A) \times 100 = ((2000-1975.38)/1975.38) \times 100 \\ &= (24.62/1975.38) \times 100 = \underline{\underline{1.25\%}}\end{aligned}$$

### Specific gravity for coarse aggregate

Weight of Saturated surface dry test samples in air (B) = 2000g

Weight of Saturated surface dry test samples in Water (C) = 1314.9g

Weight of oven dry sample in air (A) = 1975.38g

Weight of test sample Before Oven Dry (gm) = 1628.2

Weight of test sample After Oven Dry (gm) = 1609.8

Specific Gravity SSD = B / (B-C) = 2000 / (2000-1314.9)

$$= 2000/685.1 = \underline{\underline{2.92}}$$

$$\begin{aligned}\text{Bulk specific gravity (SSD basis)} &= (\text{Sp. Gr. (SSD)} / (100 + \% \text{ Abs})) \times 100 = 2.92 / (100 + 1.25) \times 100 \\ &= (2.92/101.25) \times 100 = \underline{\underline{2.88}}\end{aligned}$$

$$\begin{aligned}\text{Apparent specific gravity} &= A / (A - C) \times 100 \% = 1975.38 / (1975.38 - 1314.9) \\ &= (1975.38/660.48) = \underline{\underline{2.99}}\end{aligned}$$

$$\begin{aligned}\text{Absorption capacity} &= \left( \frac{B - \text{Oven Dry}}{\text{Oven Dry}} \right) \times 100 = ((1628.2 - 1609.8)/1609.8) \times 100 \\ &= ((18.4)/1609.8) \times 100 = \underline{\underline{1.15\%}}\end{aligned}$$

Table 4.2. Summary of test results for coarse aggregate

No.	Test description		Test result
1	Maximum size		25mm
2	Moisture content		1.25%
3	Unit wt.		1.630g/cm <sup>3</sup>
4	Absorption capacity		1.15%
5	Specific gravity	Bulk	2.88
		Bulk(SSD)	2.92
		Apparent	2.99

#### 4.1.1.2. Sieve Analysis and fineness modules of fine aggregate

The laboratory tests were carried out to identify the physical properties of the original sand sample was meeting the grading requirement. The grading requirement for fine aggregate according to ES C.D3.201 [Abebe Dinku, 2002] and the grain size distribution of the fine aggregate is as shown in Table 4.3 and Figure 4.2.

Table 4.3. Sieve analysis results and standard for fine aggregate

Sieve Size in (mm)	Mass Retained, (g)	% Retained	Cumulative % Retain	% Passing	Determination(%) passing ( ES C.D3.201)
<b>12.5</b>	0.00	0.00		100.00	100
<b>9.5</b>	1.58	0.16		99.84	100
<b>4.75</b>	15.5	1.55	1.71	98.29	95-100
<b>2.36</b>	33.34	3.33	5.04	94.96	80-100
<b>1.180</b>	55.27	5.53	10.57	89.43	50-85
<b>0.600</b>	756.0	75.61	86.18	13.82	25-60
<b>0.300</b>	88.7	8.87	95.05	4.95	10-30
<b>0.150</b>	33.63	3.36	98.41	2.6	2-10
<b>0.075</b>	10.74	1.07		0.51	
Pan	5.15	0.51		0.00	
<b>Total</b>	<b>999.98</b>		<b>FM =2.97</b>		

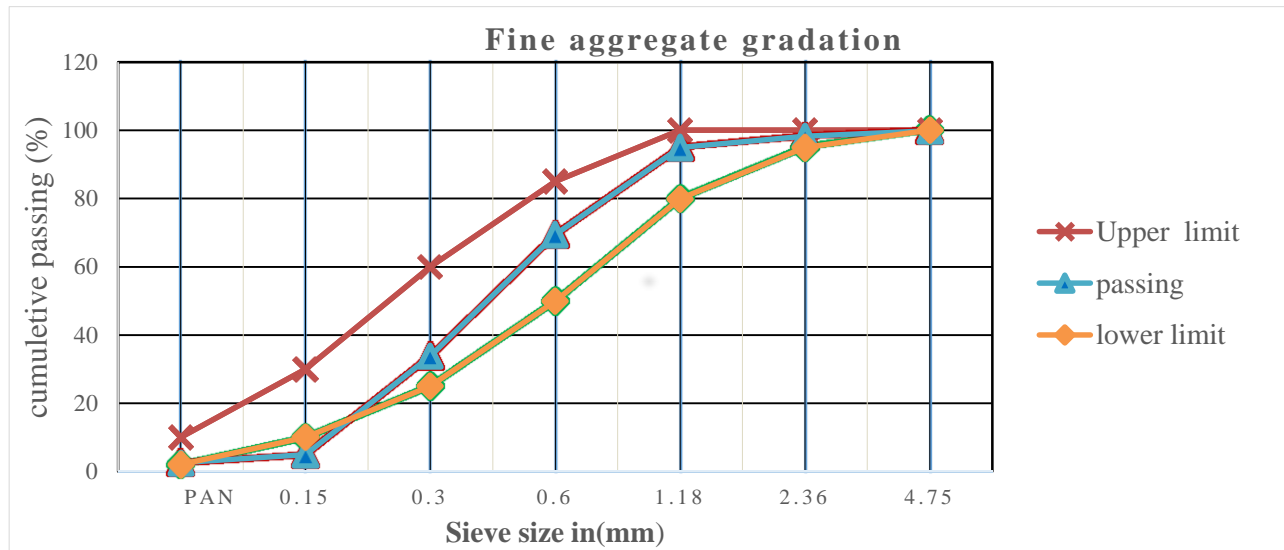


Figure 4.2. Graph for gradation of fine aggregate

$$\text{Fineness Modules} = \frac{\sum \text{cumulative coarser (\%)}}{100} = \frac{296.96}{100} = 2.97$$

#### 4.1.1.2.1. Moisture content

The water to cement ratio of a concrete affects the strength and the workability of the concrete. The increase of the w/c ratio results in a decrease of the strength of the concrete and an increase of workability. Most of the aggregates don't meet this assumption by either absorbing water (dry aggregates) or by releasing it (wet aggregates) to the mix. As a result of this property of aggregates the design water to cement ratio of the mix changes. Therefore it is important to determine both the absorption capacity and the moisture content of the aggregate. The moisture content of fine aggregates was determined by oven drying a sample of fine aggregate (1000gm) in an oven at a temperature of 110 °C for 24 hrs and dividing the weight difference by the oven dry weight.

Weight of Flask (g) = 176

Weight of SSD Test Sample (S) = 500g

Weight of Flask + SSD Test Sample = 676g

Weight of oven dry test sample (A) = 488g

Weight of flask + full of water (B) = 671.3gm

Weight of flask + Sample + full of water (C) = 952.6gm

$$\begin{aligned} \text{Water Absorption of test (Moisture content)} &= ((S-A)/A) * 100 = \frac{500-488}{488} * 100 \\ &= (12/488) * 100 = \underline{\underline{2.46\%}} \end{aligned}$$

#### 4.1.1.2.2. Specific gravity and absorption capacity

Specific gravity is an expression of the density of an aggregate. It is the ratio between the weight of the substance and that of the same volume of water. Aggregates contain pores in their structure, therefore the specific gravity depends on whether the pores are included in the measurement or not. Apparent specific gravity of an aggregate refers to the solid materials excluding the pores and bulk specific gravity refers to total volume i.e. including pores of the aggregate.

Weight of Flask (g) = 176

Weight of SSD Test Sample (S) = 500g

Weight of Flask + SSD Test Sample = 676g

Weight of oven dry test sample (A) = 488g

Weight of flask + full of water (B) = 671.3gm

Weight of flask + Sample + full of water (C) = 952.6gm

Specific Gravity SSD test Sample =  $S / (B + S - C) = 500 / (671.3 + 500 - 952.6)$   
 $= 500 / (1171.3 - 952.6) = \underline{\underline{2.286}}$

Bulk Specific Gravity (dry basis) =  $(\text{Sp.Gr. SSD}) / (100 + \% \text{ Abs}) * 100 = ((2.286) / (100 + 2.46)) * 100$   
 $= (2.286 / 102.46) * 100 = \underline{\underline{2.231\%}}$

Apparent specific gravity =  $488 / ((671.3 + 488) - 952.6) = 488 / (1159.5 - 952.6)$   
 $= 488 / 206.7 = \underline{\underline{2.419\%}}$

#### NMC Determination of sand

Weight of test sample Before Oven Dry (gm) (A) = 986.2

Weight of test sample After Oven Dry (gm) (B) = 975.7

Natural Moisture Content =  $(A - B) / B = (986.2 - 975.7) / 975.7 = \underline{\underline{1.076\%}}$

#### 4.1.1.2.3. Unit weight

The unit weight effectively measures the volume that the graded aggregate will occupy in concrete and includes both the solid aggregate particles and the voids between them. The weight of the aggregate is dependent on the moisture content of the aggregate, constant moisture content is required. Oven dried aggregate sample is used in this test [Abebe Dinku, 2002]. The unit weight of the fine aggregate sample used was found to be  $1.524\text{g/cm}^3$ . The above test results are summarized in Table 4.4 below:

Table 4.4. Summary of test results for fine aggregate

No	Test Description		Test Result
1	Silt Content		4.4%
2	Moisture Content		1.076%
3	Unit wt.		$1.524\text{g/cm}^3$
4	Absorption Cap.		2.46%
5	Specific gravity	Bulk	2.231
		Bulk(SSD)	2.286
		Apparent	2.419
6	Fineness Modulus		2.97

## 4.2 Results and discussions on Fineness of bagasse ash to cement Blended and Pastes

In this part the test results on the different properties of bagasse ash and the blended pastes are discussed and analyzed.

### 4.2.1. Physical properties of cement and bagasse ash

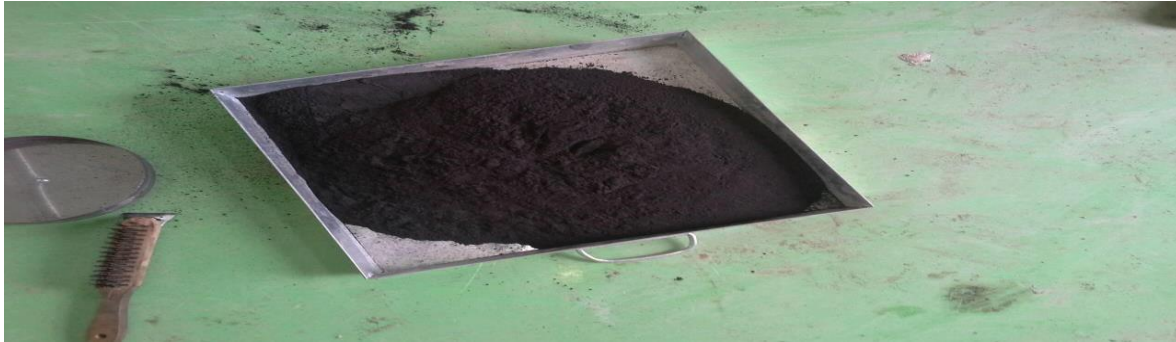


Figure 4.3. Sample of Bagasse ash after grinding

Table 4.5 .Grain size distribution for bagasse ash and Ordinary Portland Cement

Sieve size	Percentage passing (Cement)	Percentage passing (Bagasse ash)
150 $\mu$ m	100	100
125 $\mu$ m	100	99.01
75 $\mu$ m	93	89.6
63 $\mu$ m	82	85.5
32 $\mu$ m	33	38.56

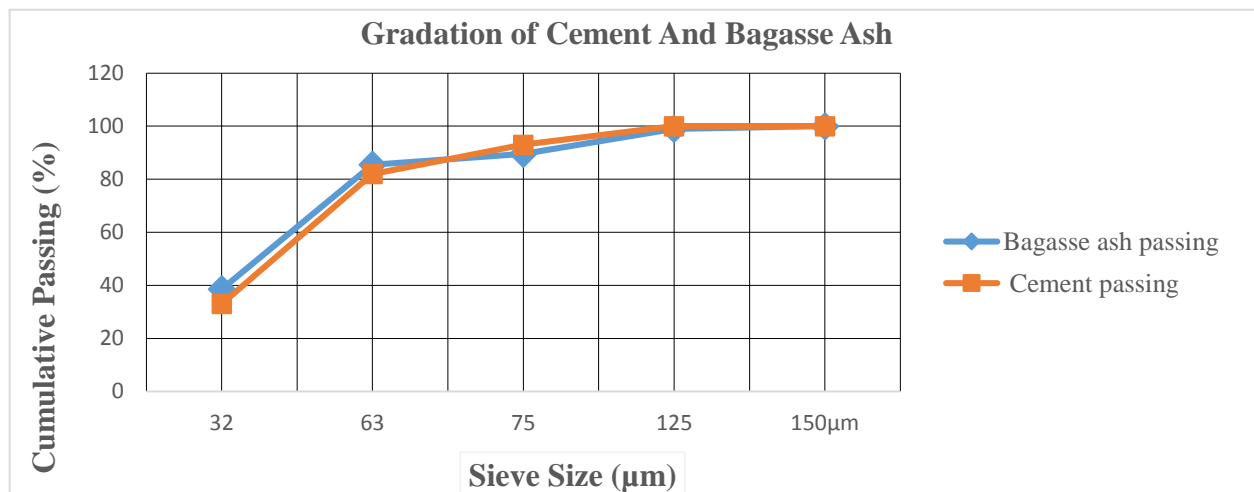


Figure 4.4. Gradations of Cement and Bagasse Ash



Particle size analysis of ash samples indicated that average size of the ash particles was 40.02 $\mu\text{m}$  and 90% of the particles were of size less than 75.8 $\mu\text{m}$ , whereas cement has an average fineness of 42.8 $\mu\text{m}$  which is greater than the ash and 90% of the particles were less than 71.7 $\mu\text{m}$  which is less than the ash. This shows that the bagasse ash is coarser than the cement for higher sieve sizes and the opposite for lower sieve sizes. This is also shown in the grain size distribution of the bagasse and the cement in Figure 4.4 This figure shows that the bagasse is finer than the cement for sieve size less than 70 $\mu\text{m}$  (where the two graphs meet) and the cement is finer for sieve sizes greater than this size, showing that the bagasse contains some particle coarser than cement but on average it is finer than cement. This would be decrease the density of the concrete significantly since concretes are casted for the same volume and replacement is made using volume based method.

**Table 4.6. Physical properties of cement and bagasse ash**

Material	Density in $\text{g/cm}^3$	Blain fineness ( $\text{cm}^2/\text{gm}$ )	Average size ( $\mu\text{m}$ )
<b>OPC</b>	3.15	3300	42.8
<b>BA</b>	2.169	4720	40.02

**N.B:** The average size of the particle is the sieve size at which 50% of the particles passes, and is determined by linear interpolation.

As shown in Table 4.6, BA has low density (2.169 $\text{g/cm}^3$ ) and higher surface area (Blaine surface area(S) =4720  $\text{cm}^2/\text{g}$ ) as compared to OPC and which is much lesser value than specific gravity of cement (density 3.15) and (Blaine surface area of cement (S) =3300  $\text{cm}^2/\text{g}$ ).

#### **4.2.1.1. Fineness of blended powders**

The fineness of bagasse ash by blain air permeability method was found to be 4720 $\text{cm}^2/\text{g}$ , which is greater than cement which was measured to have a surface area of 3300  $\text{cm}^2/\text{g}$ . The fineness of the different blended powders was also measured and is presented in Table 4.7 below:

**Table 4.7. Fineness of bagasse ash and blended powders.**

S. No	Code	Blain air (cm <sup>2</sup> /g)
1	BA 0	3300
2	BA 5	3319
3	BA10	3357
4	BA15	3494
5	Bagasse ash	4720

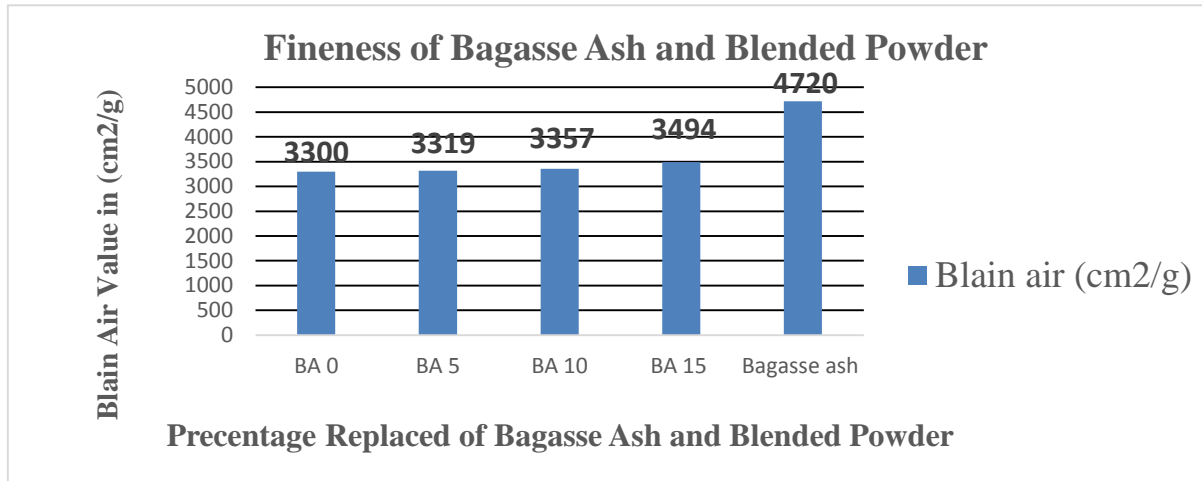


Figure 4.5. Fineness of bagasse ash and blended powders

From the results it can be seen that the blain air of the bagasse ash is higher than that of cement, and all the blended powders show a higher fineness than cement which is due to the lower density of the bagasse ash. [Ajay Goyal et al 2007.], has reported that large surface area favors the pozzolanic reactivity of amorphous silica and other minerals.

#### **4.1.1.2. Normal Consistency of blended pastes**

Normal consistency of the control paste or the paste without bagasse ash had normal consistency of 30%. Normal consistency of pastes containing bagasse ashes are shown in Table 4.8. All of the pastes containing bagasse ash shown normal consistency higher than the control paste. At 5% replacement the normal consistency had shown a slight increment to 31%, at 10% replacement the normal consistency had shown a slight increment to 32% and it increases continuously to 33% at 15% replacement. This, all of the pastes containing bagasse ash showed normal consistency higher than the control paste that increases continuously from 31% to 33% with 1% increment.

Table 4.8. Normal consistency of blended pastes containing bagasse ash

S. No	Code	Consistency (%) (ASTM C 187)
1	BA 0	30
2	BA 5	31
3	BA 10	32
4	BA 15	33

**N.B:** BA is Bagasse Ash

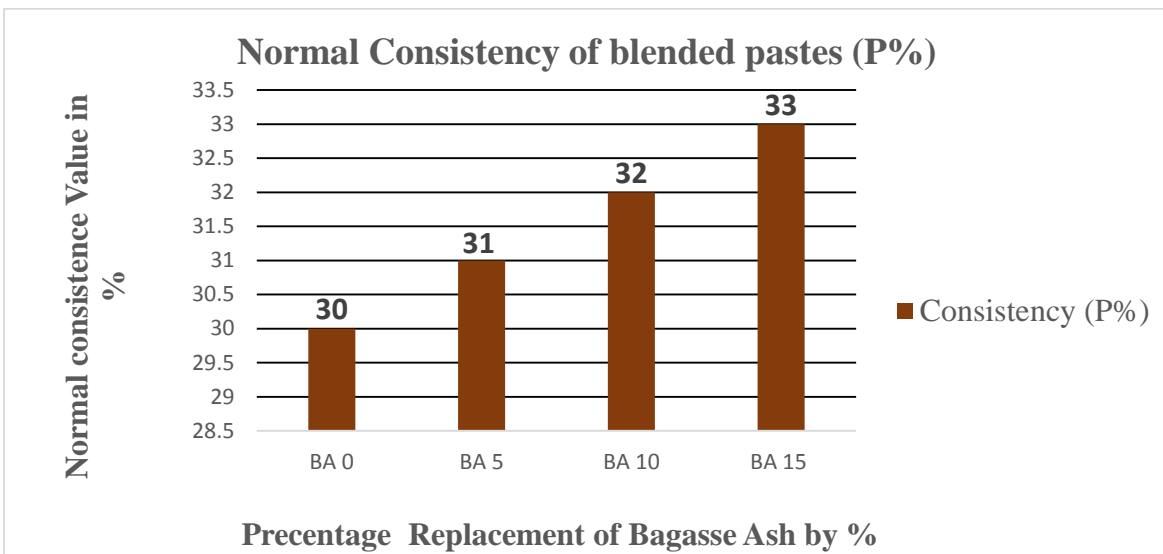


Figure 4.6. Normal consistencies of blended pastes containing bagasse ash

This finding on the consistency of the blended pastes conformed to previous researches [Nuntachai Chusilp, *et al.*, 2009]. The increment on water requirement is probably due to the higher fineness of bagasse ash ( $4720 \text{ cm}^2/\text{g}$ ) and its porosity as compared to cement.

The usual range of water to cement ratio for normal consistency is between 26% and 33% [Abebe Dinku, 2002]. The pastes with replacement up to 15% showed a consistency within this range, however, after 15% replacement the results showed slightly higher increment values.

#### 4.1.1.3. Setting time of bagasse ash to cement mix pastes

There are two types of setting time i.e. initial and final setting times. The Ethiopian standard limits the initial setting time of cement not to be less than 45 minutes and the final setting time not to exceed 600 minutes (10hrs). The results for the setting time in Table 4.9 indicated that addition of bagasse ash retarded the setting; however this retardation was within limits as specified by the Ethiopian standard.

Table 4.9.Setting time of pastes containing bagasse ash

S. No	Mix Code	Initial setting time (minutes)	Final setting time (minutes)
1	BA 0	188	330
2	BA 5	203	360
3	BA10	210	390
4	BA15	220	420

**N.B:** BA is Bagasse Ash

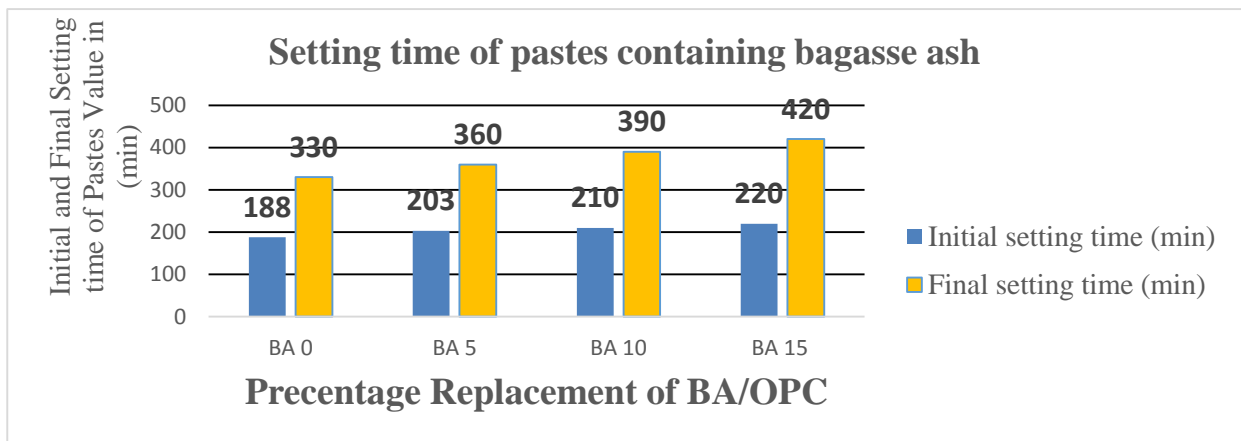


Figure 4.7.Setting time of pastes containing bagasse ash

Other researchers had also conformed to the increase in setting time of BA/OPC blended pastes. According to Ajay Goyal the probable reason for the increase in setting time could be the adsorption of water on the bagasse ash surface. The higher the proportion of the bagasse ash, the higher was the adsorption of water increasing the normal consistency which in turn retarded the setting time. Ajay Goyal also suggested that the reduction in the amount of calcium hydroxide and also the development of films of silica gel around cement grains may have caused the retardation of setting time.

#### 4.1.1.4. Soundness tests

The important property of cement after setting shall not undergo any appreciable change of volume. But, certain cements have been found to undergo a large expansion after setting causing disruption of the set and hardened mass. This will cause serious difficulties for the durability of structures when such cement is used.

Table 4.10.Soundness of Expansion pastes containing bagasse ash

Sr. No.	Mix Code	Expansion in normal temp. water for 24 hours in (mm)	Expansion in boiling for three hours in (mm)	Expansion distance of pastes
1	BA0	18	14	4
2	BA 5	16	13	3
3	BA 10	16	14	2
4	BA 15	14	13	1

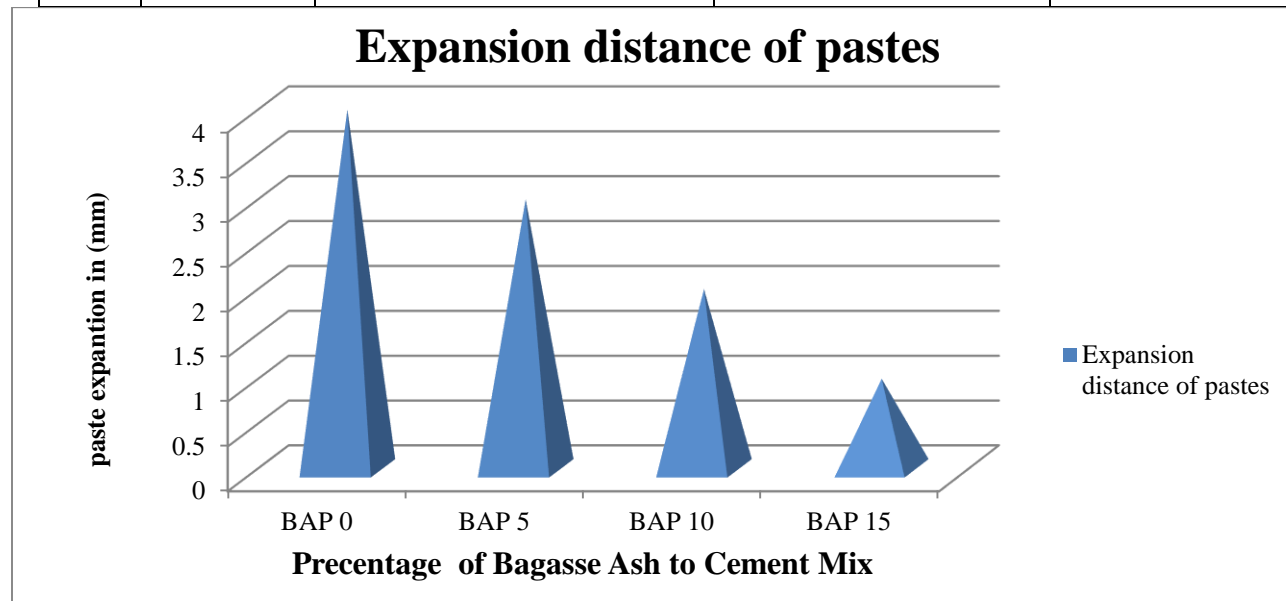


Figure 4.8.Soundness of Expansion pastes containing bagasse ash

The unsoundness in cement is due to the presence of excess of lime than that could be combined with acidic oxide at the kiln. It is also likely that too high a proportion of magnesium content or calcium sulphate content may cause unsoundness in cement. Soundness of the control paste or the paste without bagasse ash had soundness expansion 4 mm. All of the pastes containing bagasse ashes are shown in Table 4.10 was soundness expansion lower than the control paste.

And the higher the proportion of the bagasse ash, the higher was the adsorption of water increasing the normal consistency which in turn decreases the expansion of soundness of cement. The reduction in the amount of calcium hydroxide and lime in the bagasse ash and also the development of films of silica gel around cement grains may have caused the reduction of expansion distance of pastes and too high a proportion of silica compound content in the bagasse ash may cause more soundness in cement blended pastes.

#### 4.1.1.5. Chemical composition of cement and Bagasse Ash

Table 4.11. Chemical composition of cement and Bagasse Ash

Chemical Composition (%)	Dangote OPC (41)	Bagasse Ash Appendix(H)
SiO <sub>2</sub>	22.82	61.04
Al <sub>2</sub> O <sub>3</sub>	5.41	6.12
Fe <sub>2</sub> O <sub>3</sub>	3.37	3.52
CaO	66.32	1.36
MgO	1.46	2.56
Na <sub>2</sub> O	-	1.08
K <sub>2</sub> O	-	5.92
MnO	-	0.01
TiO <sub>2</sub>	-	0.28
P <sub>2</sub> O <sub>5</sub>	-	0.66
H <sub>2</sub> O	-	1.88
LOI	-	10.15
SiO <sub>2</sub> + Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub>	-	72.68

The combined chemical composition;  $\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 = 72.68 > 70\%$  satisfied the pozzolanic nature of bagasse ash as per ASTM C- 618 specifications.

According to this specification, the bagasse ash qualifies to be a Class N Pozzolan material. The loss on ignition (LOI) value for the bagasse ash was found to be 10.15% which was slightly more than that specified by the same standard (10%). Moreover the bagasse ash was found to have high alkali content like K<sub>2</sub>O (5.92%) implying high potential for alkali-silica reaction when used in concrete with silica reach aggregates.

## 4.2 .Results and discussion on Properties of concretes

The different test results on both the fresh and hardened concrete are presented and analyzed in this part of the Research.

### 4.2.1. Properties of Fresh Concrete

To assess the workability of the fresh concrete the slump test was conducted. A concrete mix should be workable enough in order to be placed, compacted and finished. The ingredients in concrete should be in such a proportion as to allow a good workability of the concrete and sufficient strength to support the required load after hardening.

The trial bagasse ash to cement mix for the control concrete gave a slump of targeted slump 25-75mm. In order to make the slump in the targeted range, the free water to cement ratio of the mix had been changed from 0.40, 0.45 to 0.50. This adjustment had resulted in a slump of 36mm which is in the required range. Table 4.12. Below gives the slump for all BA /OPC concrete mixes

Table 4.12.Slump test results W/C=0.40

Sample No	Mix Code	% of bagasse ash	water to cement ratio (W/C)	Slump in (mm)
1	BA 0	0	0.45	36
2	BA 5	5	0.4	34
3	BA 10	10	0.4	32
4	BA 15	15	0.4	27

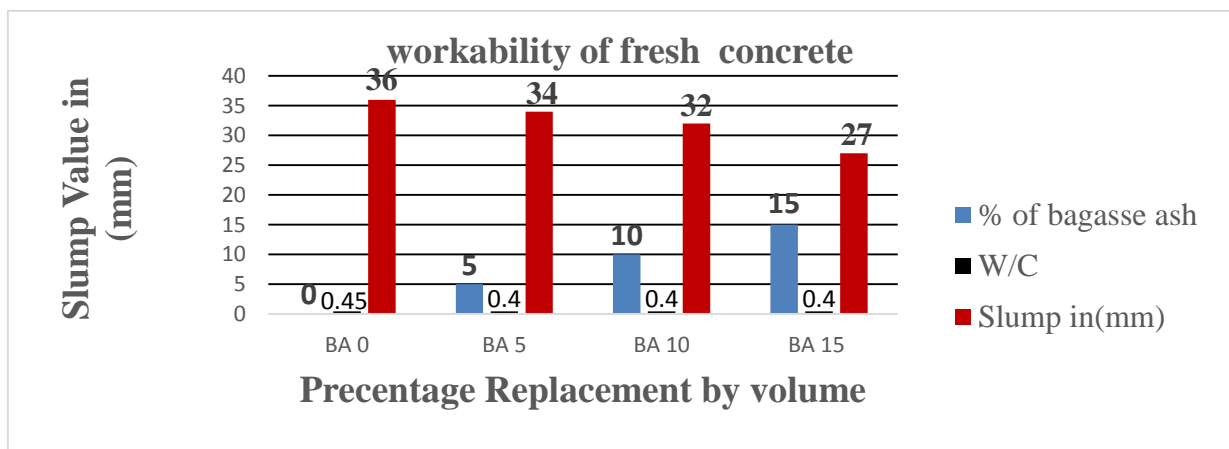


Figure 4.9.Slump test results W/C=0.40

Table 4.13.Slump test results W/C=0.45

Sample No	Mix Code	% of bagasse ash	water to cement ratio (W/C)	Slump in (mm)
1	BA 0	0	0.45	36
2	BA 5	5	0.45	36
3	BA 10	10	0.45	34
4	BA 15	15	0.45	30

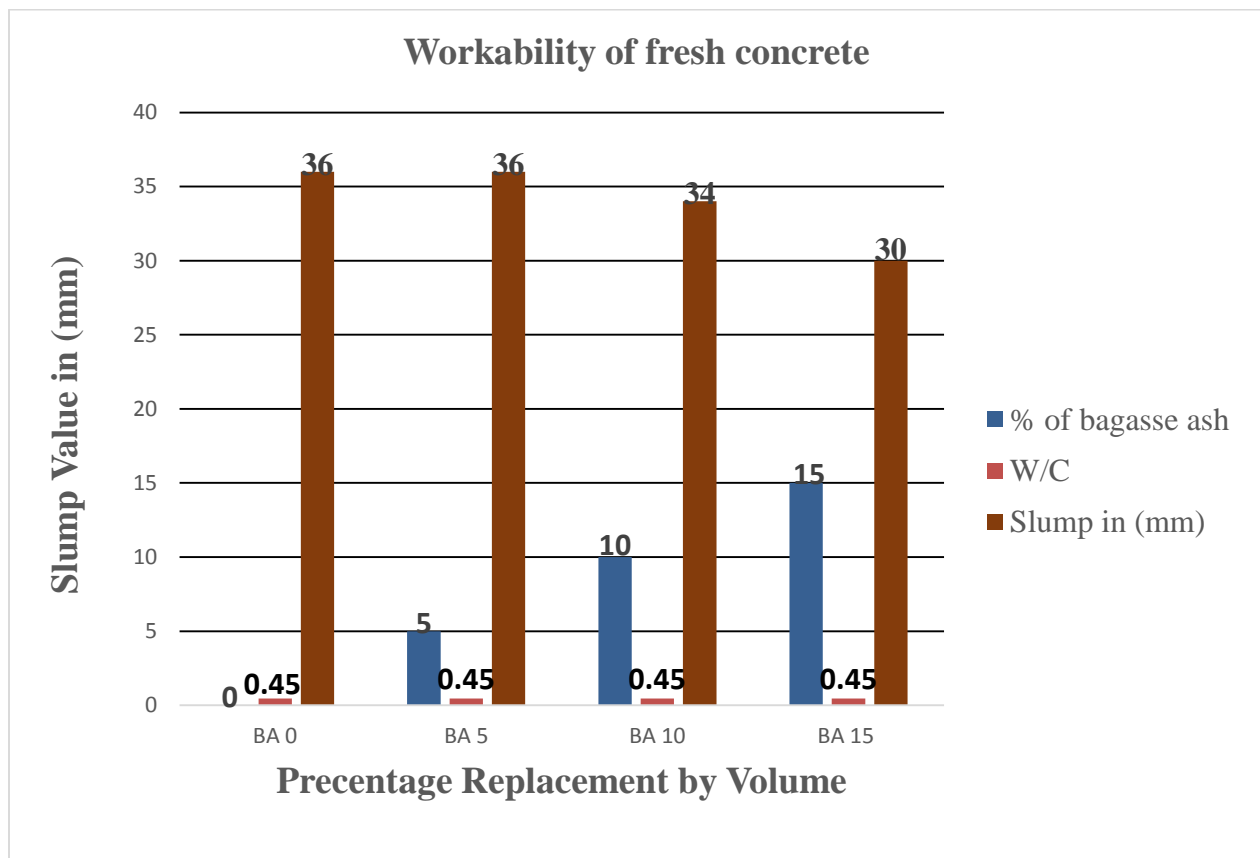


Figure 4.10.Slump test results W/C=0.45



Table 4.14.Slump test results W/C=0.50

Sample No	Mix Code	% of bagasse ash	water to cement ratio (W/C)	Slump in (mm)
1	BA 0	0	0.45	36
2	BA 5	5	0.5	47
3	BA 10	10	0.5	43
4	BA 15	15	0.5	35

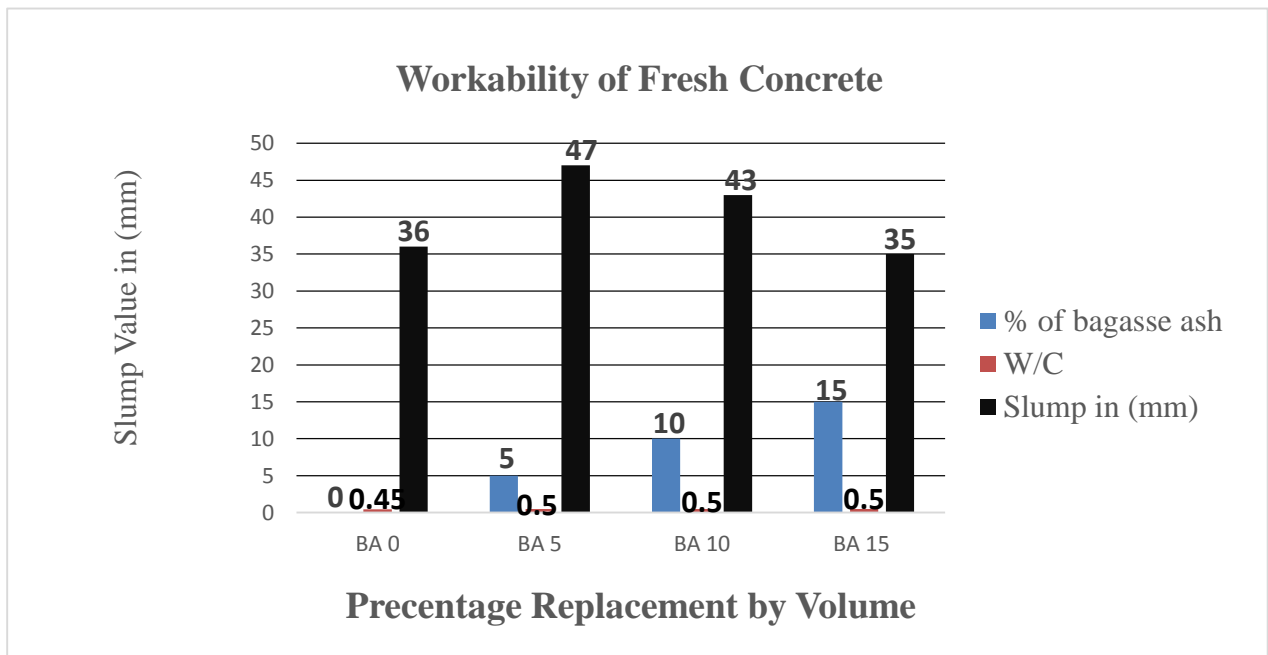


Figure 4.11.Slump test results W/C=0.50

As can be shown in Table 4.12 the slumps of the concrete containing bagasse ash have shown a slight reduction as the bagasse ash content increases. Table 4.8 (normal consistency table), shows that the normal consistency of the blended pastes increased with increase of the bagasse ash, this can also be an indication that in order to get a certain slump, BA/OPC blended concretes needs a higher water content than a concrete with no bagasse ash.

This reason may be the higher specific surface area of the bagasse ash and its lower density giving it a higher porosity, resulting in higher water demand. In order to get similar slump for the control and BA /OPC concrete, the water content can be increased as the bagasse ash content increases. And also, Figure 4.10 and 4.11 shows the slump height for both the 0.45 and 0.5 w/c ratio samples are decreasing when the amount of bagasse ash in the sample is increasing which means by the workability is decreasing. Bagasse ash has finer particles which have higher surface area compared to cement particle.

Bagasse ash particles would be filled into the spaces between the cement grains resulted in stabilizing and increase the cohesiveness of the concrete but adversely affecting the workability (G. Nithin et al., 2010). The water absorbing characteristics of Bagasse ash increase the demand of water with the increasing amount of Bagasse ash in the mixture.



Figure 4.12. Slump test of concrete

#### **4.2.2. Properties of Hardened Concrete**

This part discusses the different properties of the hardened concrete which greatly affect the performance of concrete. In this research unit weight, compressive strength of the concretes are tested and presented in the sections below.

#### 4.2.2.1 Results and discussions on unit weight of Concrete

The weights and the dimension of the concrete cubes for this research are measured just before testing them for the compressive strength. These tests were conducted at 28 days. The results for the weight and dimension are given in the appendix. In this section the unit weights of the concrete are calculated by using the 28 days weight and dimension and the results are as shown in Table 4. 15

Table 4.15.Unit weights of control and blended concretes

S. No	Mix code	Replaced OPC (%)	Unit wt. (kg/m <sup>3</sup> )	Reduction (%)
1	BA 0	0	2369	0.00
2	BA 5	5	2352	0.72
3	BA 10	10	2341	1.2
4	BA 15	15	2329	1.72

From the results, it was found out that a slight reduction of unit weight up to 1.72 % was observed when 15% of the cement was replaced by bagasse ash in sample BA 15. Whereas 0.72% and 1.12 % reductions were **observed** for 5 and 10 % bagasse ash replacement in sample BA 5 and BA 10 respectively.

The low density of the bagasse ash, 2.169g/cm<sup>3</sup>, as compared to 3.15g/cm<sup>3</sup> for that of OPC resulted in a reduction of unit weights of the blended concretes. Figure 4.13below also shows the reduction in unit weight as bagasse ash content increases.

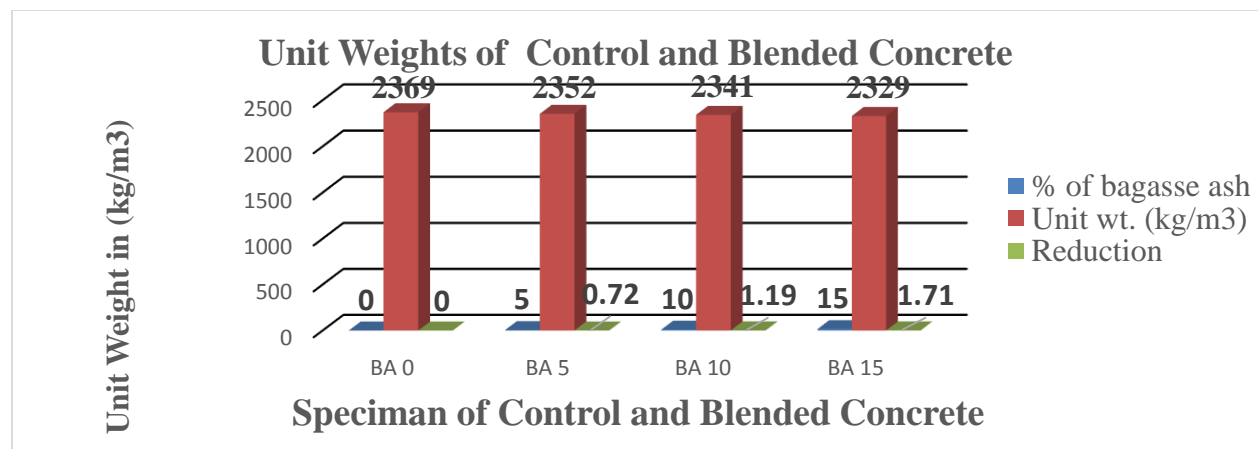


Figure 4.13. Graphical comparisons of unit weight values

Even though it is small, the concretes with the bagasse ash have shown a reduction in unit weight. A low density concrete is beneficial in many ways over a high density concrete. Using a lighter concrete, reduces the size of structural members and also reduces the pressure on formworks.

#### 4.2.2.2. Results and discussions on compressive strength of concrete

The compressive strength test of concrete is the most common test type for the hardened concrete. The reasons for these are; many codes and design manuals are based on this property, many other properties of concrete depend on the compressive strength and when compared to other tests this is an easy one to identify concrete properties. Figure 4.14 below shows a compressive strength test under progress.



Figure.4.14. Compressive strength of concrete being tested

The compressive strength of each of the concrete is determined by testing the cubes in a compression machine after 28 day curing time. Table 4.16 shows this compressive strength values: Average 28-day compressive strength test results for all 27 bagasse ash to cement mix concrete along with the standard deviation of three replicates of each mixture are presented in Table 4.16. The data given in Table 4.16. Were utilized for statistical analysis to examine the significance of the mixture factors and subsequently to obtain a regression model for compressive strength in terms of the factors considered.

Table 4.16. Compressive strength test results.

Number Mix	28-day average compressive strength, (MPa)	Standard deviation of 3 replicates of each mix (MPa)
1	35.64	5.994
2	37.46	3.190
3	36.86	3.067
4	38.55	1.815
5	39.19	0.781
6	40.8	1.833
7	34	4.859
8	37.92	1.820
9	28.2	0.854
10	28	3.205
11	34.34	3.72
12	36	3.289
13	33.02	6.688
14	30.67	2.643
15	38.69	5.615
16	27.15	0.5511
17	30.35	5.675
18	37.1	3.656
19	35.03	5.095
20	30.5	4.821
21	26.48	1.905
22	33	6.447
23	30.67	6.450
24	30.14	7.493
25	25.43	0.6807
26	32.91	10.11
27	30.52	6.361

#### 4.2.2.3. Statistical Analysis of Data and Fitting of the Compressive Strength Model.

Analysis of variance (ANOVA) was carried out to pinpoint the individual and interactive effects of variable factors on the dependent variable. ANOVA of the test results in the present study was done with the software MINITAB 18 used. Based on the ANOVA results, the polynomial regression model for compressive strength was obtained.

The results of ANOVA for compressive strength are presented in Table 4.17A factor was considered to have significant effect on the compressive strength if value was found to be less than 0.05 (95%

confidence level). The value was obtained from Fisher's distribution table which depends on error degree of freedom (DF) and the mean squares (MS). Table 4.17 shows that the significant effects on compressive strength as their levels of significance, p-value, is less than 0.05. Therefore, this significant variable should be considered for obtaining the regression model for compressive strength. Although the effect on compressive strength is found to be insignificant because it varies within a narrow range of 5% to 15% bagasse ash, it is considered in the regression analysis as bagasse ash to cement mix remains an indispensable material in concrete production.

Table 4.17. Analysis of Variance (ANOVA) for compressive strength test results

Source	DF	SS	MS	F-Value	P-Value	Significance
W/C Ratio	2	162.46	81.23	3.30	0.045	Yes
BA/OPC	2	90.08	45.04	1.83	0.171	No
FA/TA	2	102.57	51.29	2.08	0.135	No
W/C Ratio*BA/OPC	4	156.26	39.07	1.59	0.192	No
W/C Ratio*FA/TA	4	103.03	25.76	1.05	0.393	No
BA/OPC*FA/TA	4	62.10	15.52	0.63	0.643	No
W/C Ratio*BA/OPC*FA/TA	8	202.11	25.26	1.03	0.429	No
Error	52	1281.35	24.64			
Total	80	2537.69				

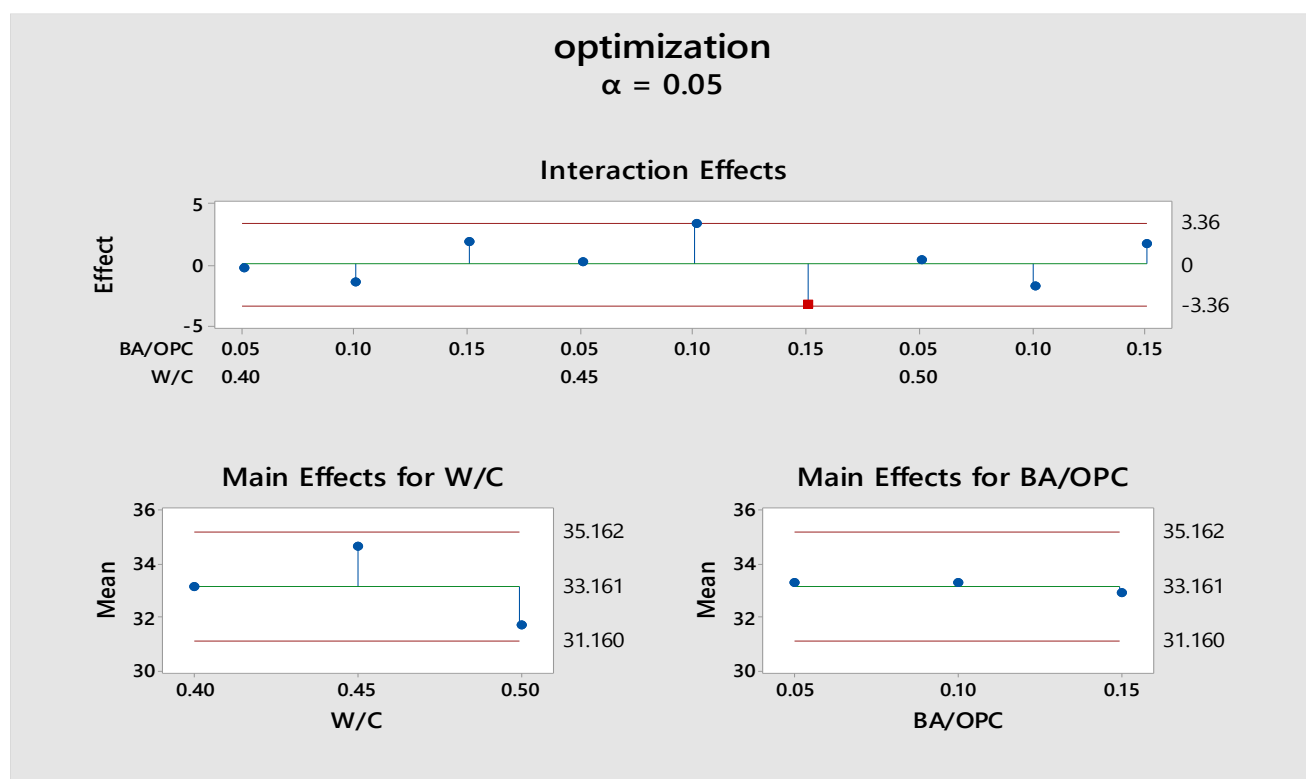


Figure 4.15. Main effects and the interaction effects for W/C at different levels of BA/OPC

The polynomial regression model obtained for compressive strength using the data presented in Table 4.13 is presented as follows:

### Regression Equation

BA/OPC			
<b>0.05</b>	$f_c'$ (Mpa)	=	$-61 -0.056BA/OPC - 19.87Exp( 2.083*W/C \text{ Ratio})+162.25FA/TA^{0.119}$
<b>0.1</b>	$f_c'$ (Mpa)	=	$-61 -0.056BA/OPC - 19.87Exp( 2.083*W/C \text{ Ratio})+164.25FA/TA^{0.119}$
<b>0.15</b>	$f_c'$ (Mpa)	=	$-61 -0.056BA/OPC - 19.87Exp( 2.083*W/C \text{ Ratio})+161.25FA/TA^{0.119}$

where  $f_c'$  (Mpa): the 28-day compressive strength in MPa, BA/OPC is the cementitious material content in  $kg/m^3$ , W/C Ratio the water/cementitious materials ratio by mass and FA/TA is the Fine/Total aggregate ratio by mass The upper and lower bounds of each of the three variables are given in Table 3.1

#### 4.2.2.4. Optimization of BA/OPC Mix Proportions Using Compressive Strength Model

The Empirical model obtained for compressive strength can be used for optimization of Bagasse Ash to Cement mix proportions using any suitable optimization method/tool. The developed compressive strength model was utilized for optimization of bagasse ash to cement mix concrete corresponding to the following options typically using the Microsoft Excel Solver:

1) Optimizing the levels of the achieving maximum possible compressive strength at different values of cementitious materials content within the selected range 5%, 10% and 15% bagasse ash (i.e., 19.89, 39.78 and 59.67 kg/m<sup>3</sup> bagasse ash that supplements cement by weight and 377.91, 358.02 and 338.13 kg/m<sup>3</sup> cements).

2) Optimizing the levels for achieving different target compressive strengths at different values of cementitious materials content within the selected range 5%, 10% and 15% bagasse ash (i.e., 19.89, 39.78 and 59.67 kg/m<sup>3</sup> bagasse ash that supplements cement by weight and 377.91, 358.02 and 338.13 kg/m<sup>3</sup> cements).

The optimization results, presented in table 4.18 indicate that the maximum compressive strength corresponding to a cementitious materials content of 10% bagasse ash (i.e. 39.78/358.02) kg/m<sup>3</sup> is higher than that at cementitious materials contents of 5% and 15% bagasse ash (i.e. 19.89/377.91 and 59.67/338.13) kg/m<sup>3</sup>. Further, the maximum compressive strength at cementitious materials content of 5% bagasse ash is higher than that corresponding to a cementitious materials content of 15% bagasse ash. This indicates that, at the same optimum values of the compressive strength is more at lower cementitious materials content (i.e., at a higher aggregate to cement ratio) due to better aggregate packing, as reported by Neville and Brooks [Neville, A. M., 1994]. At all levels of the cementitious materials content, maximum compressive strengths correspond to minimum water/cementitious materials ratio (0.4) and maximum fine/total aggregate ratio (0.45) within their ranges of variation considered in the present work.



Table 4.18.Optimization of Bagasse Ash to Cement Mix Proportion

Optimization option	$f_c$ (MPa)	Optimum Levels of Bagasse Ash to Cement Mix			
		(W/C By mass)	BA/OPC (By mass)	FA/TA (by mass)	Cost level
1) Optimizing the levels of W/C Ratio and FA/TA for achieving maximum compressive strengths at different levels of BA/OPC	40.6	0.4	5/95	0.45	High
		0.4		0.45	
	42.4	0.4	10/90	0.45	Medium
	39.7		15/85		Low
1) Optimizing the levels of W/C Ratio and FA/TA for achieving different target compressive strengths at different levels of BA/OPC	35.64	0.5	5/95	0.4	High
	37.46	0.46		0.42	
	36.86	0.42		0.44	
	36	0.49	10/90	0.41	Medium
	38.55	0.45		0.42	
	38.69	0.4		0.44	
	33.02	0.48	15/85	0.41	Low
	34.34	0.43		0.43	
	35.03	0.4		0.45	

From Table 4.18. the bagasse ash to cement mix proportion of concrete having a maximum compressive strength of 42.4 Mpa at cementitious materials content of bagasse ash 10%, water/cementitious materials ratio of 0.4 and fine/total aggregate ratio of 0.45 can be selected as the optimum of Bagasse Ash to Cement mix proportion. However, in cases where the compressive strength requirement is less than the maximum, a set of water/cementitious materials ratio, cementitious materials content, and fine/total aggregate ratio other than the optimum one can be selected for achieving the workability and durability requirements.

The data obtained from the optimization option (2), as presented in Table 4.18, were plotted to depict the variations of compressive strength with water/cementitious materials ratio and fine/total aggregate ratio at different cementitious materials contents, as shown in figures 4.16 and 4.17, respectively.

Table 4.19. From Optimization of Bagasse Ash to Cement Mix Proportion the changed to by mass in (kg)

S.No	code mix	(W/C By mass)	BA/OPC(Kg/m3)	FA/TA (by mass)	$f_c'$ (MPa)
1	BA0	45	100	45	38.58
2	BA5	40	19.89	45	40.8
3	BA10	40	39.79	45	42.4
4	BA15	40	59.67	45	39.7
5	BA5	50	19.89	40	35.64
6	BA5	46	19.89	42	37.46
7	BA5	42	19.89	44	36.86
8	BA10	49	39.79	41	36
9	BA10	45	39.79	42	38.55
10	BA10	40	39.79	44	38.69
11	BA15	48	59.67	41	33.02
12	BA15	43	59.67	43	34.34
13	AB15	40	59.67	45	35.03

**N.B:** W/C ratio which is 0.4, 0.45 and 0.5 and BA/OPC 0.05, 0.1 and 0.15 and also FA/TA ratio 0.35, 0.4 and 0.45 are changed to by mass in (kg)

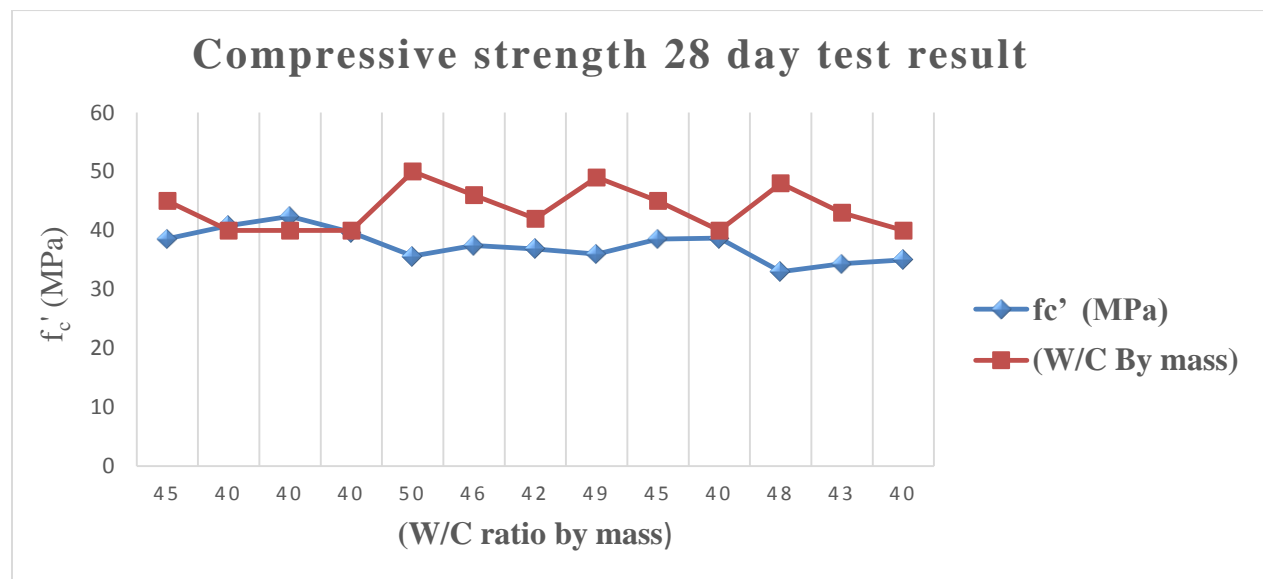


Figure 4.16. Variation of compressive strength with W/C at different levels.

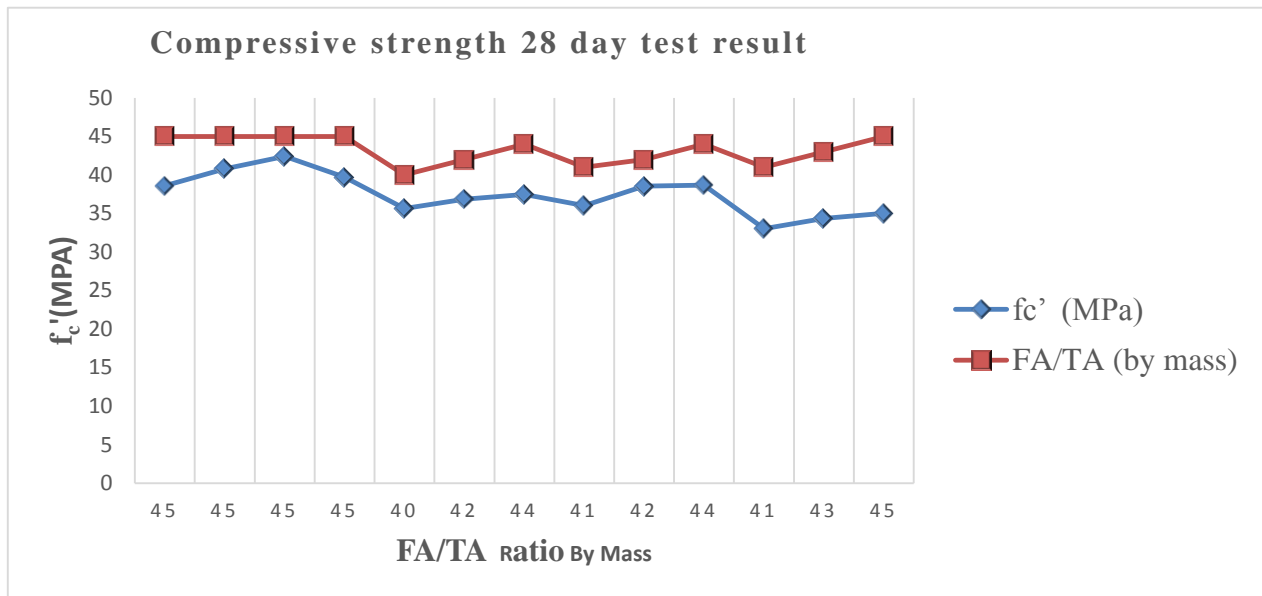


Figure 4.17. Variation of compressive strength with FA/TA at different levels.

It can be seen from figures 4.16 and 4.17 that, at a given the water/cementitious materials ratio decrease the compressive strength increases, with increase in the fine/total aggregate ratio. It can be observed from figure 4.16 that, for the same value of compressive strength, the requirement for water/cementitious materials ratio is lower at higher values of the cementitious materials content. Therefore, the plots presented in figure 4.16 can be utilized to select an adequate value of the water/cementitious materials ratio and cementitious materials content for a given value of the target compressive strength satisfying the workability and durability requirements. for example, in the case of a normal exposure, a higher value of the water/cementitious materials ratio and a lower value of cementitious materials content can be selected which would give more workability at a lower cost, whereas, for harsh exposure conditions, a lower value of the water/cementitious materials ratio and a higher value cementitious materials content can be selected, which would provide better durability.

The investigation of this thesis has conducted that bagasse ash to cement mix proportion cementitious materials content of bagasse ash 5% to 10% results in a better compressive strength than that of the control concrete with 100% ordinary Portland cement. And the compressive strength decreases as the bagasse ash replacement increases over 10%. And also, all of the BA/OPC blended concrete satisfies the ASTM C 618.

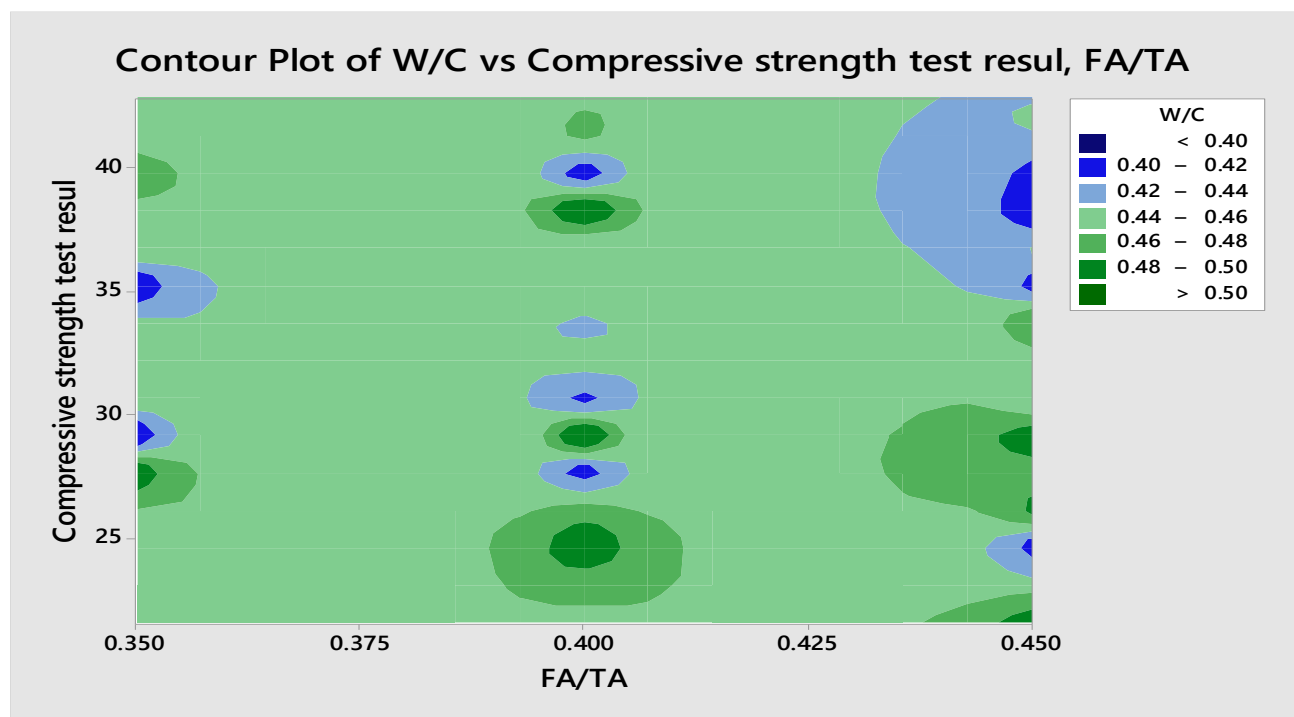


Figure 4.18. Variation of Durability with W/C ratio at different levels of BA/OPC

From the contour plot Figure 4.18, the space initially taken up by water is partially or completely replaced by hydration production as hydration reactions precede. Hydration products are produced by a reaction between cement and water. If the w/c ratio is low, complete hydration is not possible because there is insufficient space for the hydration products. Conversely, if available water exists in cement, hydration will progress continuously and the available space within the paste will be completely filled, [Abebe Dinku, 2002] suggested that the heat evolution rate starts to decrease as the w/c ratio decreases after a certain time.

The ability of the concrete to transmit fluids through it caused by pressure head, this property of concrete plays a great role in the durability of the concrete because it controls the entry of moistures which may contain aggressive chemicals and the movement of water during heating and freezing. Most pozzolanic materials were found to decrease the permeability of concrete due to the bagasse ash reaction and their higher fineness. The bagasse ash reaction consumes the free lime in the concrete and the higher fineness of the bagasse ash fills pores in the concrete both resulting in a lower permeability. For cement pastes hydrated to the same degree, the permeability is lower the higher the cement content of the paste.

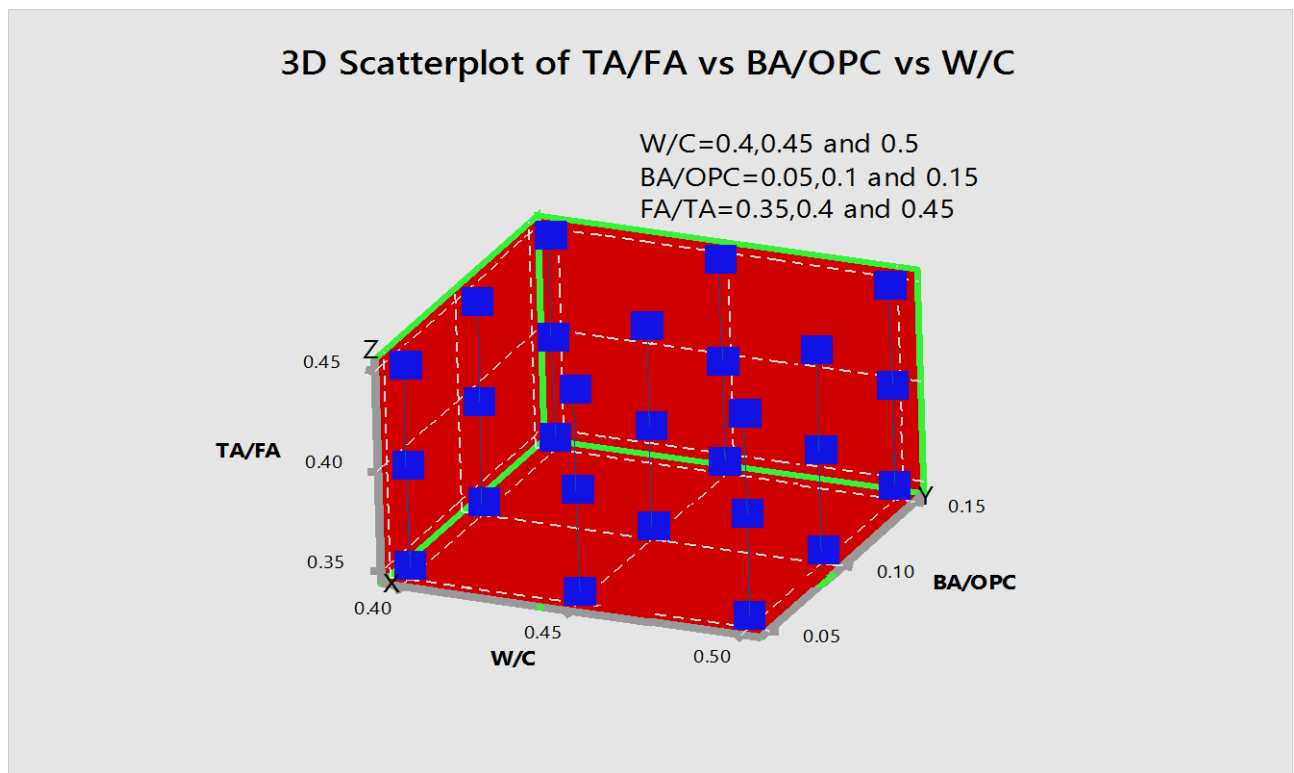


Figure 4.19. The Scatter of W/C ratio at different levels of BA/OPC with FA/TA

From this cubical optimization module we observe that for a combination of factor and levels that simultaneously satisfy the criteria placed on each of the responses and factors of 27 runs. To include a response in the optimization criteria it must have a model fit through analysis or supplied via an equation. Factors are automatically included “in range, the three inputs (factors) W/C Ratio, BA/OPC and FA/TA ratio that are considered important to the operation of Contour and 3D surface plots of the desirability function at each optimum can be used to explore the function in the factor space.

## 5. CONCLUSIONS AND RECOMMENDATIONS

The Conclusions and Recommendations that could be drawn from the results of this research and experiments are summarized as follows:

### 5.1. Conclusions

The use of bagasse ash to cement mix proportion for M30 grade concrete bagasse ash to cement blended material in concrete production was studied and after the research work is done, the following conclusions were made:

For illustrating the utilization of the selected approach to optimizing Bagasse Ash to Cement Mix an experimental program was considered based on the analysis of the data obtained through a statistically planned experimental program.

The selected approach consists of steps, are: specification of the characteristic performance of concrete, selection of the levels of mix design factors, experimental work considering trial mixtures using full factorial experiment design for generating data to obtain statistical model for optimization, statistical analysis of experimental data and fitting of the strength model, and optimization of mixture proportions using the fitted strength model.

The physical and chemical composition of bagasse ash investigated that can be assigned as class N pozzolana, as prescribed by ASTM C 618, i.e.  $\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$  is greater than 70% during complete silicon analysis at Ethiopian geological survey center.

The consistency of the ash was found to vary from mix to mix which is one of the main problems associated with by-product materials, higher blended of bagasse ash to cement mix resulted in higher normal consistency with higher water demand for certain workability and longer setting time. But, the workability of concrete was containing bagasse ash decreases slightly as the bagasse ash content increases which are due to the higher water demand of bagasse ash.

The results of the experimental works conducted in the present study for demonstrating the utility of the selected statistical approach have indicated the significant effects of water/cementitious materials (W/C) ratio on compressive strength.

The optimum values of water/cementitious materials ratio (W/C) and fine/total aggregate ratios (FA/TA) have resulted in a higher compressive strength at a lower cementitious materials content resulting in significant cost saving in the concrete production.

However, in cases where the compressive strength requirement is less than the maximum, a set of water/cementitious materials ratio, cementitious materials content, and fine/total aggregate ratio other than the optimum one can be selected for achieving the workability and durability requirements.

The investigation of this thesis has conducted that bagasse ash to cement mix proportion from 5% to 10% results in a better compressive strength than that of the control concrete with 100% ordinary Portland cement. And the compressive strength decreases as the bagasse ash to cement blended increases over 10%. Slightly, all of the BA /OPC blended concrete satisfy the ASTM C 618.

Since bagasse ash is a by-product material, it used as a bagasse ash to cement blended material reduces the levels of CO<sub>2</sub> emission by the cement industry and also saves a great deal of original raw materials. In addition its use resolves the disposal problems associated with it in the sugar industries.

The results of the concrete work considered that, the unit weight of the concretes containing bagasse ash have shown a slight reduction. It was found that a reduction of unit weight up to 1.72% was observed when 15% of the cement was replaced by bagasse ash.

Finally the results of bagasse ash to cement mix blended material with bagasse ash up to 10% is optimum. For this blended results in similar concrete properties to that of the control concrete. Higher bagasse ash to cement mix percentages can also be used with a slight reduction in the performance of the concrete.

## **5.2. Recommendations**

Recommendations for future research works by the academic community, for stakeholders and practitioners are discussed based on the findings of this research, the following recommendations are forwarded:

- ❖ Optimizations of bagasse ash to cement mix proportion as investigated in this research work can be used as a cement replacing material with economical safe, light weight structural and environmental benefits. Then concerned bodies like cement industries, sugar industries, and government entities should be made aware about this potential bagasse ash to cement mix proportion and promote its standardized production and usage.
- ❖ Test on durability of the bagasse ash to cement mix proportion can be carried out to test the hydrochloric acid resistance and water penetration.
- ❖ From this experiment showed that 10% bagasse ash to cement mix proportion for M30 Grade concrete gives maximum compressive strength. But it also requires finding various properties of concrete like Modulus of elasticity, Split tensile test, Flexure test with variation of bagasse ash in concrete.
- ❖ The cement and sugar factories in collaboration with higher education organizations in the country should work together and establish a research team to further study the use of bagasse ash to cement mix proportion as a cement replacing material.



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## APPENDIX

### APPENDIX -A

#### Specific Gravity Calculation for Bagasse Ash

##### C-1: Specific gravity (density) for bagasse ash according to ASTM D854

Weight of pycnometer =46.1g

Weight of bagasse ash+ Weight of pycnometer+ Weight of water =159.3 g,

T=21.5°c Weight of pycnometer+ Weight of water =159.3 g, T=19.5°c

$$G_{T_b} = \frac{M_o}{(M_o + (M_a - M_b))}$$

M<sub>o</sub> =mass of oven dry bagasse ash

M<sub>a</sub> =mass of pycnometer filled with water at T<sub>b</sub>

M<sub>b</sub>=mass of pycnometer filled with water and bagasse ash at T<sub>b</sub>

T<sub>b</sub>=temperature of contents of the pycnometer when mass M<sub>b</sub> was determined.

$$GT_b = \frac{\text{density of water@ T19.5} * (M_a @ 19.5 - M_f M_o)}{((\text{density of water @21.5}))}$$

Density of water at T19.5°c=998.34

M<sub>a</sub> at T 20°c=145.8

Density of water at T21.5°c=997.9

M<sub>f</sub>=46.1

$$M_a 22 = \frac{\text{density of water@ T19.5} * (M_a @ 19.5 - M_f M_o)}{((\text{density of water @21.5}))}$$

$$GT_b 22 = \frac{\text{density of water@ T19.5} * (M_a @ 19.5 - M_f M_o)}{((\text{density of water @21.5}))}$$

$$= 998.34 * (145.8 - 46.1) / (997.9) + 46.1$$

$$= 145.844g$$

$$GT_b 22 = 25 / (25 + (145.844 - 159.3))$$

$$= 2.169$$

## APPENDIX –B

### Calculation of bagasse ash fineness

#### B-1 Air Permeability Method (Blaine Method)

The method is comparative rather than absolute known specific surface is required for calibration of the apparatus.

The weight of the bagasse ash is calculated from  $m_1 = 0.500 \times \rho \times V$  [g]

Where  $\rho$  = is the density of the bagasse ash [ $\text{g.cm}^{-3}$ ]

$V$  = volume of the bagasse ash bed [ $\text{cm}^3$ ]

Specific surface area  $S$  is expressed as

$$S = (K / \rho) * \sqrt{e^3 / (1-e)} * \sqrt{t / \sqrt{0.1} \eta} \dots\dots\dots \text{eqn (3.1)}$$

Where  $K$  = is the apparatus constant

$e$  = porosity of the bed

$t$  = the measured time [s]

$\rho$  = density of cement (bagasse ash) [ $\text{g.cm}^{-3}$ ]

$\eta$  = the viscosity of air at the test temperature [Pa.s]

With the specified porosity of  $e = 0.500$

$$K = 1,414 * S_o \times \rho_o \frac{\sqrt{0.1}}{\sqrt{t_o}} \eta$$

Specific surface area (blain air) of cement ( $S$ ) =  $K\sqrt{t}$

$$S = 612.795 \sqrt{29 \text{ sec}} \quad S = 3300 (\text{cm}^2/\text{g})$$

In the same procedure the blain air of bagasse ash and blended powder was listed in the following table.

S.No.	porosity of the bed (e)	Viscosity of air from table ( $\eta$ ) in [Pa.s]	apparatus constant (k)	measured time in [s]	Code	Blain air(S) in ( $\text{cm}^2/\text{g}$ )
1	0.500	0.00001824	612.795	00:00:29	BA 0	3300
2	0.500	0.00001824	596.11	00:00:31	BA 5	3319
3	0.500	0.00001824	596.11	00:00:32:7	BA 10	3357
4	0.500	0.00001824	596.11	00:00:34:4	BA 15	3494
5	0.500	0.00001824	609.35	00:60:02	bagasse ash	4720

## APPENDIX -C

### Mix design calculation for concrete

#### C-1: Mix design of concrete according to ACI Procedure

Water to binder ratio (W/B) = 0.45

Slump height= 25-75 mm

Nominal size of aggregate= 25 mm

The concrete will be non-air entrained since the structure is not exposed to severe weathering. The estimated mixing water content based on a slump and Aggregate size is found to be 179kg/m<sup>3</sup>.

Fineness modules of fine aggregate=2.97

Amount of cement=179/0.45 =397.8kg

Coarse aggregate= volume of dry rodded aggregate per unit volume of concrete\*unit weight of aggregate.

=0.67 \*1630 =1092.1kg

#### Concrete density

0.33(specific gravity of fine aggregate) +0.67(specific gravity of coarse aggregate)

=0.33\*2.23 +0.67\*2.88

= **2.67**

#### C-2Calculated the theoretical concrete density

Fine Aggregate	Specific Gravity (Gs)	2.23
	Water Absorption (WA)	2.46%
	Natural Moisture Content (NMC)	1.08%
	Fineness Modulus (FM)	2.97
Coarse Aggregate	Specific Gravity (Gs)	2.88
	Water Absorption (WA)	1.25%
	Natural Moisture Content (NMC)	1.15%
	Nominal Max. Size	25 mm
	Dry Rodded Unit Weight	1630 Kg/m <sup>3</sup>

**APPENDIX -D****Normal consistency of pastes****D-1: Normal consistency of control cement**

Trial No.	cement (gm)	Water (wt %)	Penetration depth(mm)	time (min)	Normal trial consistency (%)
1	400	112	7	3	28
2	400	116	8.5	5	29
3	400	120	10.5	4	30

**E-1: Normal consistency Bagasse Ash blend to cement**

Trial No.	cement (gm)	Bagasse Ash 5% in (gm)	Water (wt %)	Penetration depth(mm)	time (min)	Normal trial consistency (%)
1	380	20	120	7.5	3	30
2	380	20	122	8	4	30.5
3	380	20	124	10	3	31
Trial No.	cement (gm)	Bagasse Ash 10% in (gm)	Water (wt %)	Penetration depth(mm)	time (min)	Normal trial Consistency (%)
1	360	40	124	8		31
2	360	40	126	8.5		31.5
3	360	40	128	10.5		32
Trial No.	cement (gm)	Bagasse Ash 15% in (gm)	Water (wt %)	Penetration depth(mm)	time (min)	Normal trial consistency (%)
1	340	60	128	7		32
2	340	60	130	8.5		32.5
3	340	60	132	10		33



## APPENDIX-E

### Setting time test for bagasse ash to cement mix

#### E-1: Setting time of control cement test

No.	Cement (gm)	Water (0.85p)	Penetrattion Depth(Mm)	Time	Time in (Min)	Remark
1	400	102	43	5:00	0:00	initial setting time obtained by interpolating penetration depth b/n 26&22 at 25mm was 188 min
	400	102	42	5:30	30	
	400	102	40	6:00	60	
	400	102	39	6:30	90	
	400	102	35	7:00	120	
	400	102	31	7:30	150	
	400	102	26	8:00	180	
	400	102	22	8:30	210	Final setting time was 330 min
	400	102		9:00	240	
	400	102		9:30	270	
	400	102		10:00	300	
	400	102		10:30	330	

#### E-2: Setting Time of Bagasse Ash blend to cement test

2	Bagasse Ash blend to cement by 5%(gm)		Water (0.85p)	Penetration Depth(mm)	Time	Time in (Min)	Remark
	OPC (gm)	BA 5% in (gm)					
	380	20	105.4	43	5:20	0:00	initial setting time obtained by interpolating penetration depth b/n 28&24 at 25 mm was 203 min
	380	20	105.4	41	5:50	30	
	380	20	105.4	38	6:20	60	
	380	20	105.4	35	6:50	90	
	380	20	105.4	32	7:20	120	
	380	20	105.4	30	7:50	150	
	380	20	105.4	28	8:20	180	
	380	20	105.4	24	8:50	210	Final setting time was 360 min
	380	20	105.4		9:20	240	
	380	20	105.4		9:50	270	
	380	20	105.4		10:20	300	
	380	20	105.4		10:50	330	
	380	20	105.4		11:20	360	

**E-3: Setting Time of Bagasse Ash blend to cement test**

3	Bagasse Ash Blend To Cement By 10%(gm)		Water (0.85p)	Penetration Depth(mm)	Time	Time in (Min)	Remark
	OPC (gm)	BA 10 % in(gm)					
	360	40	108.8	43	3:10	0:00	initial setting time obtained at penetration depth 25mm was 220 min
	360	40	108.8	43	3:40	30	
	360	40	108.8	41	4:10	60	
	360	40	108.8	36	4:40	90	
	360	40	108.8	34	5:10	120	
	360	40	108.8	31	5:40	150	
	360	40	108.8	27	6:10	180	
	360	40	108.8	25	6:40	210	
	360	40	108.8		7:10	240	Final setting time was 390 min
	360	40	108.8		7:40	270	
	360	40	108.8		8:10	300	
	360	40	108.8		8:40	330	
	360	40	108.8		9:10	360	
	360	40	108.8		9:40	390	

**E-4: Setting Time of Bagasse Ash blend to cement test**

4	Bagasse Ash Blend To Cement By 15%(gm)		Water(0.85p)	Penetration Depth(mm)	Time	Time in (Min)	Remark
	OPC (gm)	BA 15% in (gm)					
	340	60	112.2	43	3:30	0:00	initial setting time obtained by interpolating penetration depth b/n 26 & 23 at 25mm was 220 min
	340	60	112.2	43	4:00	30	
	340	60	112.2	40	4:30	60	
	340	60	112.2	39	5:00	90	
	340	60	112.2	36	5:30	120	
	340	60	112.2	31	6:00	150	
	340	60	112.2	28	6:30	180	
	340	60	112.2	26	7:00	210	
	340	60	112.2	23	7:30	240	Final setting time was 420 min
	340	60	112.2		8:00	270	
	340	60	112.2		8:30	300	
	340	60	112.2		9:00	330	
	340	60	112.2		9:30	360	
	340	60	112.2		10:00	390	
	340	60	112.2		10:30	420	

## APPENDIX-F

### Workability Calculation for Concrete

#### F-1: Slump test results for W/C=0.40 according to ACI Procedure

S. No	Water content W/C	Mix Code	Cementitious materials BA/OPC, (kg /m <sup>3</sup> )	Fine/Total Aggregate by mass Kg		Observed Slump (mm)
				FA	CA	
1	179.01	BA 0	397.8	598.78	1105	36
2	159.12	BA 5	19.89	598.78	1105	35
3	159.12	BA 5	19.89	729.5	1105	35
4	159.12	BA 5	19.89	870.075	1105	32
5	159.12	BA 10	39.78	598.78	1105	35
6	159.12	BA 10	39.78	729.5	1105	33
7	159.12	BA 10	39.78	870.075	1105	30
8	159.12	BA 15	59.67	598.78	1105	29
9	159.12	BA 15	59.67	729.5	1105	27
10	159.12	BA 15	59.67	870.075	1105	25

**F-2: Slump test results for W/C=0.45 according to ACI Procedure**

S. No	Water content W/C	Mix Code	Cementitious materials BA/OPC, (kg/m <sup>3</sup> )	Fine/Total Aggregate by mass Kg		Observed Slump (mm)
				FA	CA	
1	179.01	BA 0	397.8	598.78	1105	36
2	179.01	BA 5	19.89	598.78	1105	37
3	179.01	BA 5	19.89	729.5	1105	35
4	179.01	BA 5	19.89	870.075	1105	36
5	179.01	BA 10	39.78	598.78	1105	36
6	179.01	BA 10	39.78	729.5	1105	34
7	179.01	BA 10	39.78	870.075	1105	32
8	179.01	BA 15	59.67	598.78	1105	33
9	179.01	BA 15	59.67	729.5	1105	31
10	179.01	BA 15	59.67	870.075	1105	26

**F-3: Slump test results for W/C=0.5 according to ACI Procedure**

S. No	Water content W/C	Mix Code	Cementitious materials BA/OPC, (kg/m <sup>3</sup> )	Fine/Total Aggregate by mass Kg		Observed Slump (mm)
				FA	CA	
1	179.01	BA 0	397.8	598.78	1105	36
2	198.9	BA 5	19.89	598.78	1105	51
3	198.9	BA 5	19.89	729.5	1105	48
4	198.9	BA 5	19.89	870.075	1105	42
5	198.9	BA 10	39.78	598.78	1105	47
6	198.9	BA 10	39.78	729.5	1105	44
7	198.9	BA 10	39.78	870.075	1105	38
8	198.9	BA 15	59.67	598.78	1105	41
9	198.9	BA 15	59.67	729.5	1105	34
10	198.9	BA 15	59.67	870.075	1105	30

S.NO .	Water Cement Ratio	Cement	Bagasse Ash by %	FA/TO	Weight of concrete cube	Volume	Compressive strength test result	Average
1	0.45	100	0	0.45	8.09	3375	38.3	38.58
2	0.45	100	0	0.45	8.04	3375	37.9	
3	0.45	100	0	0.45	7.89	3375	39.6	
1	0.4	95	5	0.35	7.99	3375	28.8	35.64
2	0.4	95	5	0.35	8.085	3375	40	
3	0.4	95	5	0.35	8.08	3375	38.1	
4	0.4	95	5	0.4	8.075	3375	41	37.46
5	0.4	95	5	0.4	7.965	3375	36.6	
6	0.4	95	5	0.4	8.15	3375	34.8	
7	0.4	95	5	0.45	8.27	3375	35.3	36.86
8	0.4	95	5	0.45	8.245	3375	40.4	
9	0.4	95	5	0.45	8.14	3375	34.9	
10	0.4	90	10	0.35	7.975	3375	36.6	38.55
11	0.4	90	10	0.35	7.9	3375	38.8	
12	0.4	90	10	0.35	7.84	3375	40.2	
13	0.4	90	10	0.4	7.95	3375	34.1	36
14	0.4	90	10	0.4	7.93	3375	36	
15	0.4	90	10	0.4	7.89	3375	37.9	
16	0.4	90	10	0.45	8.2	3375	41.2	40.8
17	0.4	90	10	0.45	8.05	3375	42.4	
18	0.4	90	10	0.45	7.805	3375	38.8	
19	0.4	85	15	0.35	8.045	3375	29.7	30.52
20	0.4	85	15	0.35	8.08	3375	33.2	
21	0.4	85	15	0.35	7.98	3375	28.7	
22	0.4	85	15	0.4	8.16	3375	39.4	37.92
23	0.4	85	15	0.4	8.095	3375	38.5	
24	0.4	85	15	0.4	8.02	3375	35.9	
25	0.4	85	15	0.45	8.2	3375	27.4	28.2
26	0.4	85	15	0.45	8.17	3375	29.1	
27	0.4	85	15	0.45	7.93	3375	28.1	

## APPENDIX-G

### Compressive Strength of Concrete

**G-2: Compressive Strength of Concretes with W/C=0.45 for control and 0.45 for blended**


S.NO .	Water Cement Ratio	Cement	Bagasse Ash by %	FA/TO	Weight of concrete cube	Volume	Compressive strength test result	Average
1	0.45	100	0	0.45	8.09	3375	38.3	38.58
2	0.45	100	0	0.45	8.04	3375	37.9	
3	0.45	100	0	0.45	7.89	3375	39.6	
1	0.45	95	5	0.35	7.6	3375	24.9	28
2	0.45	95	5	0.35	7.91	3375	27.8	
3	0.45	95	5	0.35	7.755	3375	31.3	
4	0.45	95	5	0.4	8.075	3375	35.2	34.34
5	0.45	95	5	0.4	8.035	3375	30.3	
6	0.45	95	5	0.4	8.15	3375	37.6	
7	0.45	95	5	0.45	8.135	3375	35.1	36
8	0.45	95	5	0.45	8.115	3375	33.2	
9	0.45	95	5	0.45	8.23	3375	39.6	
10	0.45	90	10	0.35	8.065	3375	40.6	33.02
11	0.45	90	10	0.35	8.12	3375	31.3	
12	0.45	90	10	0.35	8.295	3375	27.2	
13	0.45	90	10	0.4	8.255	3375	30.5	30.67
14	0.45	90	10	0.4	8.075	3375	32.7	
15	0.45	90	10	0.4	8.045	3375	28.8	
16	0.45	90	10	0.45	8.145	3375	41	38.69
17	0.45	90	10	0.45	8.19	3375	42.8	
18	0.45	90	10	0.45	7.76	3375	32.3	
19	0.45	85	15	0.35	7.84	3375	27.8	27.15
20	0.45	85	15	0.35	7.825	3375	26.9	
21	0.45	85	15	0.35	7.85	3375	26.8	
22	0.45	85	15	0.4	7.95	3375	25.5	30.35
23	0.45	85	15	0.4	7.915	3375	36.6	
24	0.45	85	15	0.4	7.815	3375	29	
25	0.45	85	15	0.45	7.93	3375	40.6	37.1
26	0.45	85	15	0.45	7.975	3375	37.3	
27	0.45	85	15	0.45	7.8	3375	33.3	

**G-3: Compressive Strength of Concretes with W/C=0.5 for control and 0.45 for blended.**

S.NO .	Water Cement Ratio	Cement	Bagasse Ash by %	FA/TO	Weight of concrete cube	Volume	Compressive strength test result	Average
1	0.45	100	0	0.45	8.09	3375	38.3	38.58
2	0.45	100	0	0.45	8.04	3375	37.9	
3	0.45	100	0	0.45	7.89	3375	39.6	
1	0.5	95	5	0.35	8.09	3375	29.2	35.03
2	0.5	95	5	0.35	7.975	3375	36.8	
3	0.5	95	5	0.35	8.03	3375	39.1	
4	0.5	95	5	0.4	8.185	3375	33.3	30.5
5	0.5	95	5	0.4	7.96	3375	33.2	
6	0.5	95	5	0.4	8.295	3375	24.9	
7	0.5	95	5	0.45	8.09	3375	25.4	26.48
8	0.5	95	5	0.45	8.01	3375	28.7	
9	0.5	95	5	0.45	8.155	3375	25.4	
10	0.5	90	10	0.35	8.045	3375	39.3	33
11	0.5	90	10	0.35	7.825	3375	33.3	
12	0.5	90	10	0.35	8.07	3375	26.4	
13	0.5	90	10	0.4	8.145	3375	33.4	30.67
14	0.5	90	10	0.4	8.27	3375	35.3	
15	0.5	90	10	0.4	8.25	3375	23.3	
16	0.5	90	10	0.45	8.24	3375	24.8	30.14
17	0.5	90	10	0.45	8.06	3375	26.9	
18	0.5	90	10	0.45	8.05	3375	38.7	
19	0.5	85	15	0.35	7.98	3375	25.2	25.43
20	0.5	85	15	0.35	7.895	3375	24.9	
21	0.5	85	15	0.35	7.93	3375	26.2	
22	0.5	85	15	0.4	7.955	3375	36.4	32.91
23	0.5	85	15	0.4	7.86	3375	40.8	
24	0.5	85	15	0.4	7.82	3375	21.5	
25	0.5	85	15	0.45	7.92	3375	34.1	34
26	0.5	85	15	0.45	7.905	3375	38.2	
27	0.5	85	15	0.45	7.89	3375	29.6	

# APPENDIX -H

## Chemical Composition of Bagasse Ash

	<b><u>GEOLOGICAL SURVEY OF ETHIOPIA</u></b>		Doc. Number: GLD/F5.10.2	Version No: 1
	<b><u>GEOCHEMICAL LABORATORY DIRECTORATE</u></b>			Page 1 of 1
Document Title:	Complete Silicate Analysis Report		Effective date:	May, 2017

Issue Date: - 23/05/2018

Request No: GLD/TR/316/18

Report No: GLD/TR/0332/18

Sample Preparation: - 200 Mesh

Number of Sample: One (1)

Customer Name:- Teshale Feyera Goshu(AASTU)

Sample type: - Bagass Ash

Date Submitted: - 10/05/2018

Analytical Result: In percent (%) Element to be determined Major Oxides & Minor Oxides

Analytical Method: LiBO2 FUSION, HF attack, GRAVIMETRIC, COLORIMETRIC and AAS

Collector's code	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	Na <sub>2</sub> O	K <sub>2</sub> O	MnO	P <sub>2</sub> O <sub>5</sub>	TiO <sub>2</sub>	H <sub>2</sub> O	LOI
TFG-01	61.04	6.12	3.52	1.36	2.56	1.08	5.92	<0.01	0.66	0.28	1.88	10.15

**Note:** - This result represent only for the sample submitted to the laboratory.

### Analysts

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### Checked By



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Gosa Haile



### Quality Control



Awash Yitga



## APPENDIX -I

### Photos of Sample Taking Time and Test Time Shown

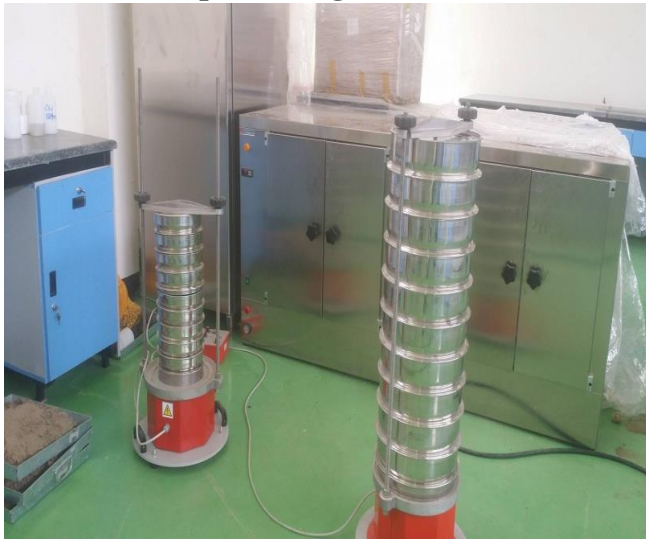


Photo 1: A) Sieve Analysis of Sand Analysis



B) Balanced Coarse Aggregate for Sieve



Photo 2: A) Compacted test of Sand



B) Unit Weight test of Coarse Aggregate



Photo 3: A) Silt Content Test of Sand B) Sample of Bagasse Ash



Photo 4: A) Soundness test of Bagasse Ash Blended paste B) Bagasse Ash Balanced for Sieve Analysis





Photo 5: A) Unit weight test of Bagasse Ash      B) Setting time test of Bagasse Ash to Cement mix



Photo 6: A) Concrete Mixing and Workability test      B) Casted Concrete stored in moist air for 24hours



Photo 7: A) Concrete Cured in the water for 28 days      B) Concrete surface dried in air for 2hrs

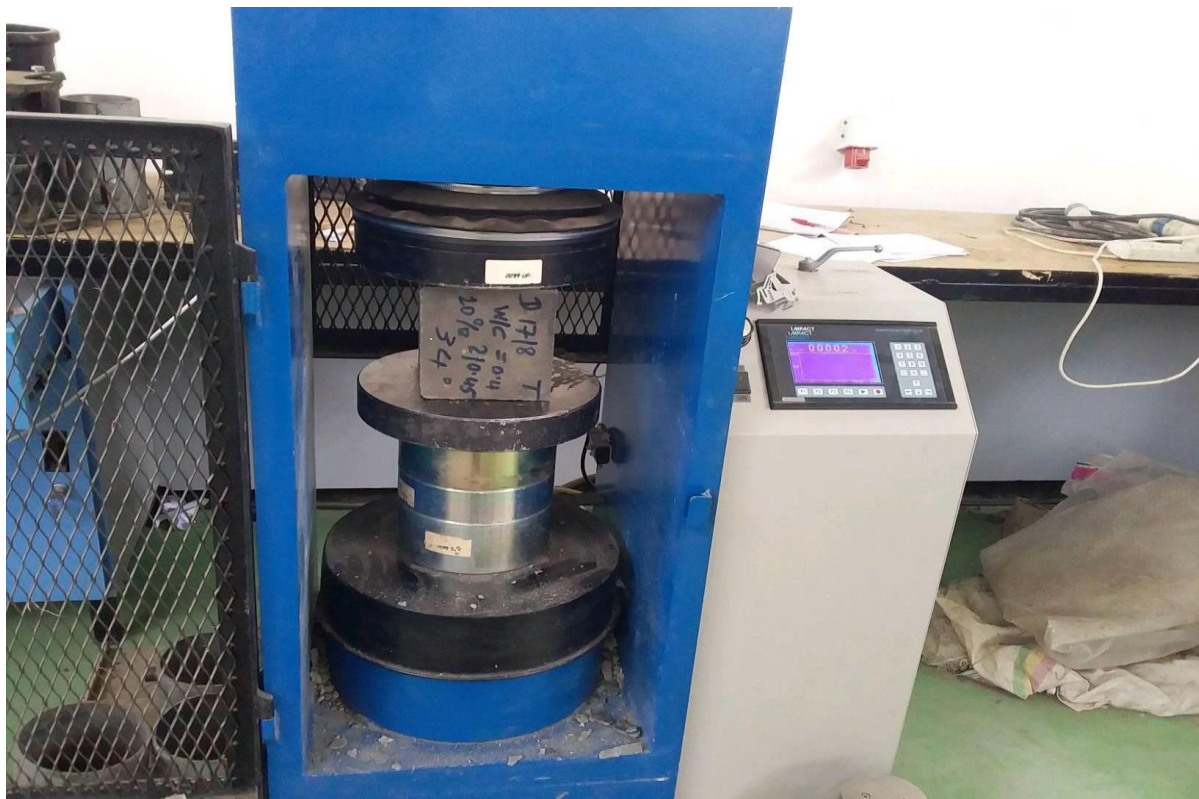


Photo 8: A) Compressive Strength of Concrete test After 28 days